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MYSIS RELICTA AS INTERMEDIATE HOST OF AN ACANTHOCEPHALAN PARASITE

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ABSTRACT

A cystacanth (Acanthocephala: Echinorhynchidae) was found in each of two specimens of *Mysis relicta* collected from Green Lake, Green Lake County, Wisconsin. The occurrence of the acanthocephalans in *Mysis* and the ability of *Mysis* to act as an intermediate host for other fish parasites should result in caution in any attempts to transplant *Mysis* into lakes in order to enhance their fisheries potential.

INTRODUCTION

Brownell (1970) studied the possibility that *Mysis relicta* (Loven) and *Pontoporeia affinis* (Lindstrom) could serve as intermediate hosts of the acanthocephalan *Echinorhynchus salmonis* Muller. Based upon feeding experiments, it was found that *Pontoporeia* definitely was an intermediate host, but that no infections occurred due to the feeding on *Mysis* by the lake trout. It was therefore considered that *Mysis relicta* would be a good organism to transplant into lakes where incomplete food chains occurred in order to enhance the fisheries potential of these lakes.

The lack of acanthocephalan parasites in *Mysis* was confirmed for southwestern Lake Michigan by Amin (1978) in studying the occurrence of acanthocephalan cystacanths in *Mysis* and *Pontoporeia*. In the dissection of 2,161 specimens of *Mysis*, Amin (1978) did not find any cystacanths, though he did find one cestode proceroid, *Cyathocephalus truncatus* Pallas. Smith and Lankester (1979) reported on the development of swim bladder nematodes in *Mysis*.

In May of 1979, two specimens of *Mysis* were collected from Green Lake, Green Lake County, Wisconsin, one of which had a cystacanth partially emerge during the preservation in ethanol. A cystacanth was later found in the other specimen and both were identified as members of the family Echinorhynchidae, but could not be further identified due to the proboscis being inverted. *Mysis* is a natural inhabitant of Green Lake, recorded from this site as early as 1924 (Juday and Birge, 1927).

The presence of this acanthocephalan in *Mysis*, and the apparent ability of *Mysis* to serve as an intermediate host for other fish parasites should lead to precautions in transplantation of *Mysis* to new lakes to prevent the introduction of new fish parasites or a better host. Though new research efforts should be undertaken to assess these risks, *Mysis* can still be considered one of the best candidates for transplantation. Pennak (1978) considered *Mysis* "a logical artificial transplant" due to its niche being unoccupied in most lakes. He also indicated that *Mysis* has been introduced into lakes in western Canada, Colorado, Wisconsin, Minnesota, New York, California, Nevada, Sweden and Russia. Each transplantation effort should be preceded by a careful study of the population to determine the presence of any parasites in *Mysis*. The population to be transplanted should then be held for a period of time to determine if any of the crustaceans have indications of infection or disease. Of value would be data on when in the life cycle or at what season are the acanthocephalans acquired by *Mysis*, and could infected individuals thus be effectively eliminated during transplantation.

ACKNOWLEDGEMENTS

Thanks to John Kennedy for the loan of the specimens and to Omar M. Amin for this help in identifying the acanthocephalans.

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WILDLIFE DAMAGE TO CORN IN SOUTHERN ILLINOIS: ASSESSMENT AND CONTROL

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ABSTRACT

In 1981, 2 techniques of controlling deer depredation to corn ears were tested in 24 plots at Union County Conservation Area: (1) HINDER, an odor repellent; and (2) a molasses-based attractant sprayed on plots of native vegetation to attract deer from crops. Ear damage was not significantly ($P > 0.1$) reduced by either technique. Four species of depredators and 1 disease were encountered. Depredator species differed significantly ($P < 0.1$) in importance; bird damage occurred most frequently, raccoons were second in importance, and damage by squirrels and deer was minimal. Losses to disease were also minimal.

INTRODUCTION

Wildlife depredation to agricultural crops is common in the United States, and probably will intensify in the future (Swanson 1970). Many wildlife species inflict damage, but white-tailed deer (*Odocoileus virginianus*) are the most common vertebrate pests (McDowell and Pillsbury 1959). The problem of deer depredation has been studied in many states, including Florida (Stith 1969, Barker 1971), Pennsylvania (Pasto and Thomas 1954), California (Biehm 1951), and Maryland (Flyger and Thoerig 1962). In Illinois, significant depredation sometimes occurs near areas of high deer density such as state parks and refuges; the most commonly damaged crop is corn (D. Westmoreland 1982).

Traditional techniques of controlling depredation include hunting, habitat manipulation, scaring devices, fences, and chemical repellents (olfactory or taste aversive). Unfortunately, the most successful techniques are often the most expen-

sive. In a novel approach, Dasmann *et al.* (1967) used an attractant composed of molasses, salt, and water. When sprayed on native vegetation, the mixture successfully attracted deer away from sensitive areas. Wagnon and Goss (1961) used a similar solution to increase cattle use of rank weeds; however, the technique had not received further attention until now. We compared a molasses mixture and an odor repellent for control of deer depredation to field corn in southern Illinois. Our objectives were (1) to evaluate the effectiveness of the 2 control techniques, (2) to compare the impact of different depredator species, and (3) to investigate the temporal distribution of damage.

STUDY AREA

Experiments were conducted from May through September 1981 at Union County Conservation Area (UCCA), Illinois. The area is a 2500 ha section of the alluvial Mississippi River floodplain (Mohlenbrock 1975). The characteristic lowland flora and plant communities have been described by G. Westmoreland (1982). UCCA is intensively managed for wildlife, with priority given to overwintering Canada geese (*Branta canadensis*). Approximately 1000 ha are planted to corn, wheat, and milo; ¼ of each corn and milo crop is left standing to feed wildlife. As a result of abundant food and infrequent harvest, UCCA sustains large populations of deer and other wildlife species. No control measures are taken against depredating animals.

MATERIALS AND METHODS

During plant emergence, the extent of depredation was noted in all corn fields, and observations of foraging deer were recorded. On the bases of dispersion and intensity of deer use, proximity to native understory, and accessibility, we selected 3 fields for experiments. Field A was composed of 33.1 ha of corn interspersed with 2 23.8-ha strips of weeds. The southern edge was bounded by woods; other boundaries were access roads. Field B (7.1 ha) was bordered on 2 sides by woodlands, and was adjacent to a milo field on its southern edge; an access road formed the eastern boundary. Field C (10.6 ha) was surrounded by open woodlands except on its southern edge, where it was adjacent to a weedy meadow.

We tested the efficacy of the 2 control techniques during the period from ear formation to harvest. The odor repellent, HINDER (Leffingwell Chemical Co., Brea, California), was diluted with 30 parts water and applied at a rate of 3.8 l per plot. This was within manufacturer's specifications. The attractant was prepared by soaking 100 cc of candied molasses (Kandy Kid Dri-Lasses, Harvest Brands, Inc., Pittsburg, Kansas) in 3.8 l of water. After 24 h, the supernatant was separated and used for treatment. On 3 occasions 115 g of salt was added to increase its attractiveness; on 1 occasion a sticker (Vapor Gard, Miller Chemical and Fertilizer Co., Hanover, Pennsylvania) was added to enhance weathering ability. The molasses mixture was applied at a rate of 3.8 l per plot. Treatments were made with an 11.4 l back-pack sprayer (Solo 425 Jet-Pack sprayer), which was thoroughly cleaned between applications. Because of heavy rainfall during ear maturation, frequent resprayings were necessary. HINDER was applied July 9, 17-19, and 26, and August 8 and 30. The molasses was applied July 12 and 22, and August 9, 16-17, and 29.

We used different experimental designs to test the control techniques. A test block for the repellent consisted of 2 25 m^2 plots placed 10 m apart; 1 was randomly assigned treatment status, and the other served as a control. The plots were non-contiguous to allow the odor of treatment to dissipate. Observations of deer near 2 plots treated with HINDER during corn emergence indicated that a distance of 10 m between plots would minimize any effect of odor dissipation (D. Westmoreland 1982). Both plots were placed within 10 m of the field's edge to maximize depredation rates (Harrison 1979). Each test block for the attractant consisted of 4 25m^2 plots; 1 randomly selected pair (1 plot in the outer 10 m perimeter of corn, the other in nearby understory vegetation) served as a treatment, and the other pair as a control. As with repellent blocks, treatment pairs were spaced 10 m from control pairs. The understory vegetation plot of the treatment pair was sprayed with molasses. Its success was judged by the amount of depredation in the corresponding corn plot and by deer use of molasses-treated vegetation. To quantify the latter, a 5 × 0.3 m strip along the corn-adjacent edge of each plot was cleared of vegetation; deer tracks were counted in these strips twice weekly from August 2 through September 9. All plots were established during tasselling. Because they were intentionally placed in areas where depredation was common, the degree of damage per plot did not represent the actual depredation rate in fields. Two repellent and 2 attractant blocks were placed in each field; the blocks were alternated, with a minimum distance of 35 m between them.

Plants damaged prior to the first treatment were marked and excluded from later counts. The extent of depredation was measured by the relative frequency of ear damage per plot; the degree of damage to individual ears was not recorded. Damage assessments were made at 4 and 9 weeks after initial treatment. During the final count, losses were categorized as having been caused by deer (Harrison 1979), raccoons (*Procyon lotor*) (Dolbeer 1980), squirrels (*Sciurus niger* or *S. carolinensis*) (Cardinelle and Hayne 1945), or birds (Cardinelle and Hayne 1945, Dolbeer 1980). Ears lost to disease also were recorded. When plants were broken or ears were removed, we were unable to determine whether deer or raccoons had caused the loss; therefore, damage of this nature was recorded as "undetermined".

RESULTS AND DISCUSSION

Browsing began within 1 week after corn emergence. Usually this had little effect on future growth; however, some plants were lost due to uprooting and trampling. True (1932) suggested that a few deer feeding consistently on emerging plants could cause extensive losses. We observed that deer tended to feed on native vegetation at field edges and browsed emerging corn only intermittently while crossing fields. Deer actively browsed leaves when corn reached a height of about 60 cm, but the damage incurred was seldom enough to retard growth. Deer did cause losses in 1 area where large groups (>10) were observed feeding on several occasions. According to Calhoun and Loomis (1974), the most common form of corn depredation in Illinois is the removal of stalk tops when plants reach 1-1.3 m. Harrison (1979) reported this type of damage on Crab Orchard National Wildlife Refuge; it did not occur in any of our plots.

We examined 2,280 ears for depredation. The average rate of depredation for all plots combined was 26.1%. We used a two-way analysis of variance with Duncan's

multiple range test (Helwig and Council 1979) to test for differences between treatments and causes of depredation. The degree of damage per plot was not significantly ($P > 0.1$) different between any of the treatments or controls (Table 1). However, the difference in deer damage between HINDER treatment and control plots approached significance ($P = 0.12$); inadequate spacing of the plots may have interfered with our evaluation of the repellent. The results of these experiments may also have been affected by frequent heavy rainfall during the first half of the season; however, neither technique improved in performance during the drier second half (Table 2).

Surprisingly, track counts indicated that deer used molasses-treated plots less than control plots; the total number of tracks counted was 14 and 31, respectively ($P < 0.05$, t-test for dependent samples, Glass and Stanley 1970). There were no signs of consistent browsing in any of the plots. Because track counts were low and browsing was absent, we consider the difference in number of tracks anomalous.

Our results with molasses contrasted with those of Dasmann *et al.* (1967). Although the mixture used in our study was prepared differently than theirs, it was identical in color, taste, and viscosity to a mixture prepared using their formula. In our tests, the amount of cover sprayed in each field was small (100 m^2); it is possible that deer simply failed to discover the molasses-treated vegetation.

The damage caused by each depredator species is shown in Table 1. Corn smut (Blair n.d.) was the only disease encountered. Disease did not correlate with depredation rate (all species pooled) ($P > 0.05$, $r = 0.09$), so it is unlikely that animal damage predisposes ears to infection. Common grackles (*Quiscalus quiscula*) were the only birds observed feeding on corn. Although birds damaged 10.1% of the ears, they usually destroyed only a few kernels at the tips. Depredators were pooled into 3 groups ($P < 0.1$) on the basis of importance: bird and "undetermined" damage were most frequent; raccoon damage was second; and deer, squirrel, and disease were the least important causes of loss (Table 1). It should be noted that damage classified as undetermined, if properly identified, would raise the values for deer and/or raccoon depredation. There was no significant ($P \quad 0.1$) interaction effect between treatments and sources of damage, i.e., the relative importance of each depredator did not change between treatments.

We believe that most of the damage included in the undetermined category was caused by raccoons. Undetermined damage was largely comprised of plants with broken stalks. This type of damage began late during ear maturation, concurrent with the onset of raccoon damage. Deer tend to damage corn during the early milk stages of growth (Harrison 1979). Therefore, deer probably contributed little to this category.

Two-thirds of the total ear damage was incurred during the second half of ear development and maturation (Table 2). This estimate may have been exaggerated because the first "half" of the season was actually a period of 4 weeks, whereas the second "half" was 5 weeks. However, this factor alone probably did not cause the difference to be significant. We attribute the high degree of ear damage in the latter half to the onset of depredation by raccoons.

Fundamental to depredation control is the determination of which species cause problems. Because deer are highly visible in fields, they probably are often blamed for damage caused by other species. Our identifications were based on descriptions by other authors (Cardinelle and Hayne 1945, Dolbeer 1980, Harrison 1979). None of these authors mentioned directly observing a depredator inflict

damage; all of our attempts at such observations failed. A reliable method of identifying depredators on the basis of their characteristic modes of feeding would be invaluable to technicians dealing with damage situations.

The degree to which deer feed on corn in southern Illinois varies widely. In our plots, deer were not important depredators; in contrast, Harrison (1979) documented a 25% decrease in corn yield from deer depredation on Crab Orchard National Wildlife Refuge. Both of these areas support large deer herds, and are within a 50 km radius. Research into the proximate factors determining the degree of deer use of corn would facilitate effective control.

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Table 1. Frequency of ear damage by 4 species of depredators and corn smut in 24 plots treated with 2 control sprays, Union County Conservation Area, Illinois. Means with the same letter within a row or column are not significantly (P>0.1) different.

Source of damage	HINDER[1]		Molasses[1]		Mean	(SD)
	Treatment	Control	Treatment	Control		
Birds	10.7	9.5	9.1	11.1	10.1[a]	(5.4)
Undetermined (deer or raccoon)	8.3	10.9	8.1	6.3	8.4[a]	(5.6)
Raccoons	2.8	7.7	2.7	5.4	4.6[b]	(5.3)
Deer	0.2	1.6	0.7	0.3	0.7[c]	(1.3)
Squirrels	0.7	0.3	1.1	0.8	0.7[c]	(1.1)
Corn smut	1.2	1.9	1.4	1.4	1.5[c]	(1.7)
Mean	4.0[a]	5.3[a]	3.8[a]	4.2[a]		
(SD)	(5.7)	(6.1)	(4.6)	(5.1)		

[1] Percent of damage (ears/plot)

Table 2. Temporal distribution of depredation to corn ears in 24 plots during the period from silking to harvest, Union County Conservation Area, Illinois. Means with the same letter within a row or column are not significantly (P>0.1) different.

Test period	HINDER[1]		Molasses[1]		Mean
	Treatment	Control	Treatment	Control	
First 4 weeks	6.2	10.5	6.1	8.2	7.8[a]
Final 5 weeks	16.4	19.5	15.5	15.7	16.8[b]
Mean	11.3[a]	15.0[a]	10.8[a]	12.0[a]	

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VASCULAR PLANTS OF THE MANITO GRAVEL PRAIRIE TAZEWELL COUNTY, ILLINOIS

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ABSTRACT

The Manito Gravel Prairie in Tazewell County, Illinois is a 19.64 acre (7.94 ha.) preserve containing remnant gravel hill prairie and sand prairie as well as disturbed upland forest and successional fields. A total of 212 species of vascular plants representing 63 families were identified during a study conducted during the summer and fall of 1981 and spring of 1982. The only known Illinois population of Tennessee milk vetch (*Astragalus tennesseensis*) occurs in this preserve.

INTRODUCTION

The Manito Gravel Prairie (Shoop Prairie) is located about 6 miles southwest of Pekin in Tazewell County, Illinois (Section 15 and Section 22, T24N, R6W, 3PM). The prairie was evaluated by the Illinois Natural Areas Inventory in 1977 and identified as a site of state-wide significance (White, 1978). The Nature Conservancy acquired the tract in 1980 and transferred it to the Illinois Department of Conservation for dedication as a nature preserve. The Natural Land Institute assisted in its preservation.

The preserve is situated at the edge of a sand and gravel terrace in the Illinois River valley (Hunter, 1966). This terrace stretches from Pekin to Manito and forms 20 to 30 foot bluffs above the river floodplain. The Manito Gravel Prairie is within the Illinois River and Mississippi River Sand Areas Natural Division of Illinois (Schwegman, 1973).

Relatively undisturbed prairie vegetation occurs on approximately 8 acres (3.2 ha.) of the study site. This area had been used as a pasture but was never cultivated. The previous owners, the Shoop family, bought the farm in 1935. According to Henry Hintz, who farmed their land, they cultivated the level sandy upland (probably until the mid 1950's) but the land along the bluff was too steep and rough to plow. The entire tract was lightly grazed by horses and cattle until the early 1960's and was burned off nearly every spring until the late 1970's. Except

for the spring burns, the tract had been idle for nearly 20 years before it was acquired by the Department of Conservation.

METHODS

The preserve was visited 21 times during the study. Each time the entire tract was surveyed and the species noted along with habitat and relative abundance. Plants that could not be identified in the field were collected but no voucher speciments were made during this study. The site was visited once in May 1981, 4 times in June, 3 times in July, 3 times in August, twice in September and once in October. In 1982 it was visited 3 times in March, twice in April and twice in May. An effort was made to cover the entire preserve at each visit.

RESULTS AND DISCUSSION

Four major natural communities are present at the Manito Gravel Prairie preserve. (Figure 1.) These are gravel hill prairie, sand prairie, dry mesic upland forest and successional field (White, 1978). Gravel hill prairie occupies several west and southwest facing slopes at the edge of the bluff and two slopes above a ravine that dissects the bluff at the east end of the preserve. The dominant plants are *Andropogon scoparius* and *Bouteloua curtipendula*. Typical associates are *Echinacea pallida, Potentilla arguta, Amorpha canescens, Petalostemum purpureum, Oxalis violacea, Arenaria stricta, Lithospermum incisum* and *Dodecatheon meadia*. Also present in this community but much less common are *Sporobolus heterolepis, Muhlenbergia cuspidata, Anemone caroliniana* and *Wulfenia bullii*.

In a few places the soil is very thin over gravel or the gravel is on the surface. Here the vegetation is very sparse and an unusual plant community is found. *Andropogon scoparius, Bouteloua hirsuta* and, in places, *Sporobolus clandestinus* dominate. The typical forbs are *Draba reptans, Oxalis violacea, Arenaria stricta, Viola rafinesquii, Plantago virginica, Corydalis micrantha, Hedeoma hispida* and *Astragalus tennesseensis*. Some of these plants are very uncommon in central Illinois.

Sand prairie occupies the more level ground above and between the gravel hillsides. *Andropogon scoparius* is the dominant plant and characteristic forbs are *Callirhoe triangulata, Opuntia compressa, Phlox bifida, Ambrosia psilostachya, Heterotheca villosa* and *Tephrosia virginiana*.

Two ravines that cut through the bluff support dry-mesic upland forest vegetation. *Quercus rubra* dominates with some *Carya tomentosa*. Common understory plants are *Ribes missouriense, Parthenocissus quinquefolia, Smilax hispida, Eupatorium rugosum, Galium aparine, Leonurus cardiaca, Aquilegia canadensis* and *Alliaria officinalis*. This community has been disturbed by grazing and many of the typical woodland herbs are lacking. *Clematis pitcheri, Cuphea petiolata* and *Euphorbia heterophylla* are found where the woods is open and thin.

The successional field community occupies about half of the preserve. Many exotic species occur in these old fields and pastures. *Poa pratensis, Poa compressa, Tridens flavus* and *Leptoloma cognatum* are the dominant grasses. Some typical herbs are *Rumex acetosella, Fragaria virginiana, Ambrosia artemisiifolia, Medicago lupulina, Oxalis stricta, Croton glandulosus, Asclepias verticillata, Verbena stricta, Physalis heterophylla* and *Erigeron canadensis*. Saplings 3 to 4 feet high

(.9 to 1.2 m) of *Crataegus mollis*, *Gleditsia triacanthos* and *Prunus serotina* are abundant in the successional fields.

A total of 212 species of vascular plants representing 63 families were identified. Three species are ferns or fern allies, there is 1 gymnosperm species, 32 monocot species and 176 dicot species. The largest family represented is the Compositae with 30 species followed by the Poaceae with 23 species and the Leguminosae with 15 species.

Thirty-five of the species identified are alien, not native to central Illinois. This represents 16% of the species occurring at the preserve. The majority of the alien species occur in the dry sandy old fields and pastures or along the roadsides. In the least disturbed prairie only two alien species occur, *Poa pratensis* and *Rosa multiflora*.

One endangered species occurs in the preserve. *Astragalus tennesseensis* is listed as endangered in Illinois by Sheviak (1981). It is found in undisturbed gravel prairie. The prairie also provides habitat for two other species that are rare in Illinois, *Muhlenbergia cuspidata* and *Wulfenia bullii*.

The following annotated list (Table 1) follows the nomenclature of Mohlenbrock (1975). Following each species name is a brief note of its habitat and relative abundance (gp = gravel hill prairie, sp = sand prairie, uf = dry mesic upland forest, sf = successional field and rs = roadside; a = abundant, c = common, u = uncommon and r = rare). An asterisk (*) indicates the species is not native to Illinois according to Swink & Wilhelm (1979).

ACKNOWLEDGEMENTS

I wish to thank John Schwegman of the Illinois Department of Conservation and Dr. Alfred Koelling of the Illinois State Museum for assistance in the correct identification of the more difficult species, particularly the grasses and sedges.

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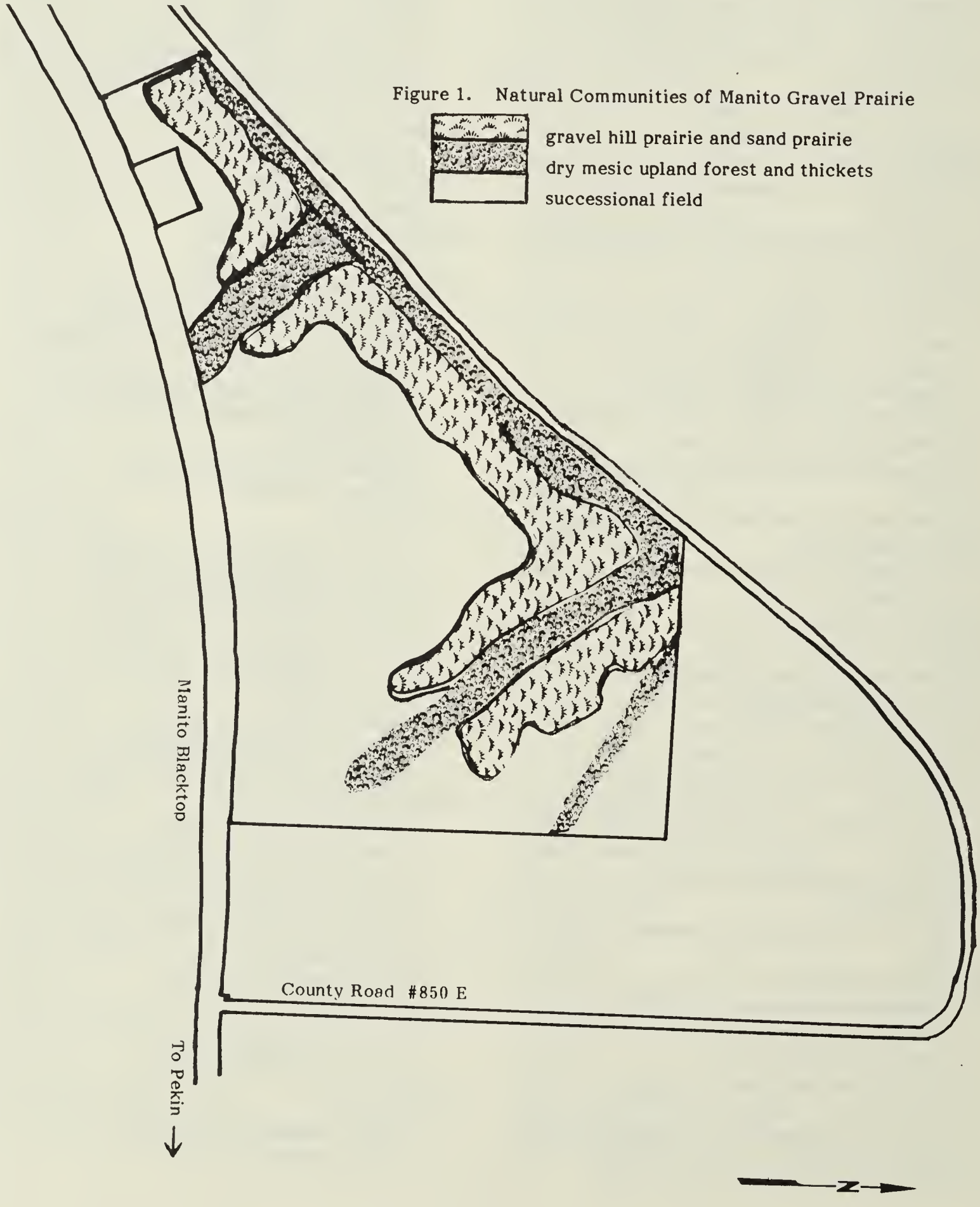
Table 1. Vascular Plants of the Manito Gravel Prairie, Tazewell County, Illinois

EQUISETACEAE
Equisetum laevigatum A.Br.-rs; u
OPHIOGLOSSACEAE
Botrychium virginianum (L.) Sw.-rs;r
POLYPODIACEAE
Asplenium platyneuron (L.) Oakes rs;r
CUPRESSACEAE
Juniperus virginiana L.-rs; r
POACEAE
**Bromus japonicus* Thunb.-sf;a
**Bromus inermis* Leyss.-sf;u
**Poa pratensis* L.-sf;a
**Poa compressa* L.-sf;a
**Phleum pratense* L.-sf;r
Elymus virginicus L.-uf,c
Elymus canadensis L.-rs,u
Leptoloma cognatum (Schult.) Chase.-sp,sf;a
Paspalum ciliatifolium Michx. sf;c
Panicum oligosanthes Schult. var. *scribnerianum* (Nash) Fern.-sp,sf;a
**Setaria viridis* (L.) Beauv.-sf;r
Sorghastrum nutans (L.) Nash.-sp,sf;a
Andropogon gerardii Vitman.-gp;r
Schizachyrium scoparium (Michx.) Nash.-gp,sp,sf;a
Eragrostis trichodes (Nutt.) Wood. sf;u
Tridens flavus (L.) Hitchcock-sf;c
Muhlenbergia cuspidata (Torr.) Rydb.-gp;u
Muhlenbergia schreberi J.F. Gmel. uf;u
Sporobolus heterolepis (Gray) Gray. gp;u
Sporobolus asper (Michx.) Kunth. sp;u
Sporobolus clandestinus (Biehler) Hitchc.-gp;c
Bouteloua curtipendula (Michx.) Torr.-gp;a
Bouteloua hirsuta Lag.-sp;c
CYPERACEAE
Cyperus schweinitzii Torr.-sp;u
Cyperus filiculmis Vahl.-sp;u
Carex muhlenbergii Schk.-sp;u
Carex blanda Dewey.-uf;c
COMMELINACEAE
Tradescantia ohiensis Raf.-sp,gp;c
**Commelina communis* L.-uf;c
LILIACEAE
Erythronium albidum Nutt.-rs,u
**Asparagus officinalis* L.-rs,sf;r
SMILACACEAE
Smilax hispida Muhl.-uf;c
SALICACEAE
Salix interior Rowlee.-rs;r
JUGLANDACEAE
Juglans nigra L.-rs,uf;u
Carya tomentosa (Poir.) Nutt.-uf;c
FAGACEAE
Quercus imbricaria Michx.-uf,rs;c
Quercus rubra L.-uf;a
Quercus macrocarpa Michx.-uf;u
ULMACEAE
Ulmus rubra Muhl.-rs;u
Celtis occidentalis L.-uf,rs;c
MORACEAE
Morus rubra L.-uf,rs;c
**Cannabis sativa* L.-rs;r
POLYGONACEAE
**Rumex acetosella* L-sf;a
**Rumex crispus* L.-rs,uf;u
**Polygonum convolvulus* L.-rs;c
Polygonum tenue Michx.-sp;r
Polygonum ramosissimum Michx.-sf;u
Polygonum virginianum L.-uf;r
CHENOPODIACEAE
Chenopodium desiccatum A.Nels-sp;u
Chenopodium standleyanum Aellen.-uf;u
AMARANTHACEAE
Froelichia gracilis (Hook.) Moq.-sf;c
NYCTAGINACEAE
Mirabilis nyctaginea (Michx.) MacM.-sp;c
PHYTOLACCACEAE
Phytolacca americana L.-rs;r
CARYOPHYLLACEAE
**Holosteum umbellatum* L.-rs;c
**Cerastium vulgatum* L.-sf;c
Arenaria stricta Michx.-gp;c
**Dianthus armeria* L.-rs,sf;r
**Lychnis alba* Mill.-rs;r
Silene stellata (L.) Ait.f.-uf,gp;c
Silene antirrhina L.-sp;c
**Saponaria officinalis* L.-rs;u
RANUNCULACEAE
Ranunculus abortivus L.-uf;c
Ranunculus fascicularis Muhl.-gp;r
Anemone caroliniana Walt.-gp;r
Anemone cylindrica Gray.-gp,rs;c
Aquilegia canadensis L.-uf;c
Clematis pitcheri Torr. & Gray.-uf,rs;c
MENISPERMACEAE
Menispermum canadense L.-uf;c
PAPAVERACEAE
Corydalis micrantha (Engelm.) Gray. sp,gp;u
CRUCIFERAE
Arabis glabra (L.) Bernh.-rs;r
Arabis shortii (Fern.) Gl.-uf;c
Descurainia pinnata (Walt.) Britt. var. *brachycarpa* (Richards.) Fern.-sp;u
Draba reptans (Lam.) Fern.-sp,sf;u
Lepidium virginicum L.-sf;c
**Alliaria officinalis* Andrz.-uf;a
SAXIFRAGACEAE
Ribes missouriense Nutt.-uf;c
Heuchera richardsonii R.Br.-gp;u
PLATANACEAE
Platanus occidentalis L.-rs,u
ROSACEAE
Prunus serotina Ehrh.-uf,rs,sf;c
Malus ioensis (Wood) Britt.-rs;c
Crataegus mollis (Torr. & Gray) Scheele. sf,rs;a
Rubus occidentalis L.-rs,sf;u
Rubus flagellaris Willd.-sf;r
Rubus allegheniensis Porter-sf;u
**Rosa multiflora* Thunb.-gp,sf;r

Potentilla arguta Pursh.-gp;c
Potentilla simplex Michx.-rs;u
**Potentilla recta* L.-sf;c
Fragaria virginiana Duchesne.-sf,rs,gp;c
Geum canadense Jacq.-uf;c
LEGUMINOSAE
Gymnocladus dioica (L.)K Koch-rs;r
Gleditsia triacanthos L.-sf,rs;a
Amorpha fruticosa L.-rs;u
Amorpha canescens Pursh.-gp,sp;c
Psoralea onobrychis Nutt.-rs;r
Cassia fasciculata Michx.-sf,sp;c
Petalostemum purpureum (Vent.) Rydb. gp,sp;c
Tephrosia virginiana (L.) Pers.-sp;r
Astragalus tennesseensis Gray.-gp;u
**Melilotus officinalis* (L.) Lam.-rs;r
**Trifolium arvense* L.-sp;r
**Medicago lupulina* L.-sf;a
**Lespedeza stipulacea* Maxim.-sf;c
Lespedeza capitata Michx.-gp,sp;c
Desmodium illinoense Gray.-gp,sp;c
OXALIDACEAE
Oxaalis violacea L.-gp;c
Oxalis dillenii Jacq.-sf,sp;c
GERANIACEAE
Geranium carolinianum L.-sf;c
RUTACEAE
Xanthoxylum americanum Mill.-rs,uf;c
Pterea trifoliata L.-rs,uf;c
EUPHORBIACEAE
Croton glandulosus L. var. *septentrionalis* Muell.-Arg.-sf;c
Acalypha rhomboidea Raf.-uf;c
Euphorbia corollata L.-sp,gp;c
Poinsettia cyanthophora (Murr.) Kl & Garcke.-uf;u
**Poinsettia dentata* (Michx.) Kl & Garcke sf;c
Chamaesyce maculata (L.) Small.-sp,sf;u
ANACARDIACEAE
Toxicodendron radicans (L.) Kuntze.-uf,rs;c
Rhus glabra L.-rs;r
Rhus aromatica Ait-sp,rs;a
CELASTRACEAE
Euonymus atropurpureus Jacq.-uf;u
HIPPOCASTANACEAE
Aesculus glabra Willd.-rs;r
RHAMNACEAE
Rhamnus lanceolata Pursh.-uf,rs;u
VITACEAE
Parthenocissus quinquefolia (L.) Planch. rs,uf;c
Vitis riparia Michx.-rs,uf,sf;c
MALVACEAE
Callirhoe triangulata (Leavenw.) Gray. sp;c
HYPERICACEAE
Hypericum sphaerocarpum Michx.-gp;c
VIOLACEAE
Viola sororia Willd.-uf;c
**Viola rafinesquii* Greene.-sf,sp;c
CACTACEAE
Opuntia compressa (Salisb.) Macbr.-sp;c
LYTHRACEAE
Cuphea petiolata (L.) Koehne.-uf;u
ONAGRACEAE
Oenothera laciniata Hill.-rs;r
Oenothera biennis L.-sf,sp;c
Oenothera rhombipetala Nutt.-sf;r
Gaura biennis L.-sp,gp;c
UMBELLIFERAE
Sanicula canadensis L.-uf;u
Spermolepis inermis (Nutt.) Math. & Constance.-sp;u
CORNACEAE
Cornus drummondii C.A. Mey.-rs,uf,gp;a
PRIMULACEAE
Dodecatheon meadia L.-gp;u
Androsace occidentalis Pursh.-sf;u
OLEACEAE
Fraxinus americana L.-uf,rs;c
APOCYNACEAE
Apocynum cannabinum L.-uf;r
ASCLEPIADACEAE
Asclepias tuberosa L.-sp;u
Asclepias verticillata L.-sf,sp;a
Asclepias viridiflora Raf.-gp;r
Asclepias amplexicaulis Sm.-sp;r
Asclepias syriaca L.-sp;c
CONVOLVULACEAE
Ipomoea lacunosa L.-rs;u
POLEMONIACEAE
Phlox bifida Beck.-sp;c
HYDROPHYLLACEAE
Ellisia nyctelea L.-uf;c
BORAGINACEAE
Mertensia virginica (L.) Pers.-uf;c
Hackelia virginiana (L.) I.M. Johnston uf;u
Lithospermum incisum Lehm.-gp;u
Onosmodium hispidissimum Mack.-gp;c
VERBENACEAE
Verbena stricta Vent.-sf,sp;c
Verbena urticifolia L.-uf;u
LABIATAE
Isanthus brachiatus (L.) BSP-gp;c
Teucrium canadense L.-rs;u
Scutellaria parvula Michx.-gp;u
Hedeoma hispida Pursh.-gp;c
**Nepeta cataria* L.-rs;u
**Leonurus cardiaca* L.-rs,uf;c
SOLANACEAE
Solanum carolinense L.-sf;u
Solanum americanum Mill.-uf;u
Physalis heterophylla Nees.-sf,sp;c
SCROPHULARIACEAE
**Veronica arvensis* L.-sf;u
Penstemon pallidus Small-gp;c
Scrophularia lanceolata Pursh.-rs,gp;u
**Verbascum thapsus* L.-sp;u
Wulfenia bullii (Eat.) Barnh.-gp;r
ACANTHACEAE
Ruellia humilis Nutt.-gp;c
PLANTAGINACEAE
Plantago aristata Michx.-sf;c
Plantago virginica L.-sp;c
Plantago rugelii Dcne.-uf;c
RUBIACEAE
Galium pilosum Ait.-uf,gp;u
Galium aparine L.-uf;c

CUCURBITACEAE
Sicyos angulatus L.-rs;r
CAMPANULACEAE
Specularia perfoliata (L.) A. DC.-sf;c
Campanula americana L.-uf;c
COMPOSITAE
Ambrosia trifida L.-rs;u
Ambrosia psilostachya DC.-sf,sp;a
Ambrosia artemisiifolia L.-sf;c
Rudbeckia hirta L.-gp, sp;u
Echinacea pallida (Nutt.) Nutt.-gp;c
**Helianthus petiolaris* Nutt.-rs;r
Helianthus tuberosus L.-rs;r
Bidens bipinnata L.-uf;u
Heterotheca villosa (Pursh) Shinners.-sp;c
Solidago juncea Ait-sp;r
Solidago canadensis L.-sp,rs;c
Aster pilosus Willd.-sf,sp;c
Aster ericoides L.-gp;u
Aster simplex Willd.-rs;r
Erigeron strigosus Muhl.-gp;c
Erigeron canadensis L.-sf;c
Achillea millefolium L.-sf,rs,sp;c
Antennaria neglecta Greene.-sp,sf;c
Gnaphalium obtusifolium L.-sf;u
Erechtites hieracifolia (L.) Raf.-gp;r
Senecio plattensis Nutt.-gp;c
Eupatorium rugosum Houtt.-uf;a
Eupatorium altissimum L.-gp,sp;c
Brickellia eupatorioides (L.) Shinners.-gp;c
**Arctium minus* (Hill) Bernh.-uf;r
Cirsium discolor (Muhl.) Spreng.-sf;r
**Tragopogon dubius* Scop.-rs,sf;r
**Taraxacum officinale* Weber.-sf;r
Lactuca canadensis L.-sp, sf;u
**Lactuca serriola* L.-sf,rs;u

Figure 1. Natural Communities of Manito Gravel Prairie



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A NEW SYRINGE METHOD FOR DETERMINATION OF DISSOLVED OXYGEN IN SMALL SAMPLES

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ABSTRACT

A new syringe method for determination of dissolved oxygen in 1.5ml samples is presented. The new method is compared to the Winkler method and to a membrane electrode with a BOD attachment; no significant differences were found between the three methods. Several possible uses for the new method are proposed.

INTRODUCTION

Dissolved oxygen (DO) concentration in natural and industrial waters is an important indicator of water quality. Respiration of aquatic organisms is dependent on DO concentrations; metabolic breakdown of organic materials (both natural and man-made) is also dependent on DO concentrations.

The classic technique for measuring DO is the iodometric Winkler method, (Winkler, 1888 in Standard Methods, 1981). This titration however, requires large water samples (300ml), and much glassware. Recently, the use of membrane electrodes has increased, becoming an acceptable alternative to the Winkler method. However, electrodes may not be convenient for intermittent use since they require frequent recalibration; in addition they are expensive to purchase and maintain.

Many papers cite micro-Winkler methods that use samples of 10ml to 60ml; for a review see Burke (1962). One micro-Winkler method we found used a 1.5ml sample and powdered reagents available in a commercial colorimetric kit (Gill 1981). However we could not duplicate the method and obtain comparable results among this proposed micro-Winkler method, the Winkler method, and the BOD probe method. The proportions suggested do not reflect logical scaling down of reagents relative to the standard Winkler method. In addition, the stated weights of the powdered reagents do not agree with our measurements; we found the weights to be off by several orders of magnitude.

Hence, this paper presents a new version of the Winkler method that is

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specifically designed for small samples (1.5ml). Our new method lends itself to biological research because it uses simple, inexpensive equipment and it is easy to prepare and titrate samples. The method is compared to the azide modification of the Winkler method Standard Methods (1981) and to a membrane electrode with a BOD attachment.

MATERIALS AND METHODS

The water samples were obtained from several sources to insure a wide range of DO values. Low range samples (0.4ppm to 2.0ppm) were obtained from a concurrent experiment that entailed measuring bivalve respiration rates in air tight, water-filled containers. Medium range samples (4.0ppm to 5.0ppm) and high range samples (7.5ppm to 10.0ppm) were obtained from tap water flowing slowly and vigorously, respectively. The samples were collected in 300ml glass BOD bottles, overflowing the neck to insure complete removal of all air bubbles. All DO measurements were taken immediately after the samples were collected to minimize changes in temperature and the possibility of outgassing.

A dissolved oxygen meter (Yellow Springs Instrument Co. INC., model 54) with a BOD probe attachment (model 5420A) was used on most samples to take the first DO reading inside the bottle. Then, two or three measurements were taken with the syringe method and averaged to give one reading. The Winkler method was used on the water remaining in the bottle to yield a third reading. All solution preparations used in the Winkler and syringe methods and the techniques of the Winkler Method followed Standard Methods (1981).

The syringe method was performed by submerging the needle tip (23 G) of a 2.5ml glass syringe beneath the surface of the sample in the BOD bottle, using a new needle for each sample. Between 1.5 and 2.0ml of water was drawn into the syringe, and the sample volume was brought to exactly 1.5ml. One minum of manganous sulfate and one minum of alkalide iodide azide solution were drawn into the syringe from inverted stoppered vials. The syringe was slowly shaken to insure complete mixing, allowed to stand in a test tube holder until the resulting flocculant settled, then reshaken. One minum of concentrated sulfuric acid was drawn into the syringe from a teflon coated septum top vial; the syringe was shaken again and when the floc had dissolved, exactly 1.0ml of the solution was expelled into a vial to be titrated. The titrant, 0.025N sodium thiosulfate, was diluted 10x with deionized water (1 part titrant to 9 parts water). The diluted titrant was drawn into a 0.5ml glass syringe and the solution was titrated to a pale straw color. Three drops of starch indicator were added and titration continued. The end point was reached when the solution was clear. Dissolved oxygen values were calculated from the relationship:

$$0.1\text{ml titrant} = 0.01\text{ppm oxygen}$$

The data were analyzed using the General Linear Model Procedure (PROC GLM) for two-way analysis of variance, SAS Institute (1979).

RESULTS

The dissolved oxygen values obtained for the ten different samples by the three techniques are presented in Table I. Two-way analysis of variance revealed no significant difference between the 3 techniques ($F = 0.98$, $P = 0.58$).

DISCUSSION

Our syringe method proves to be an accurate technique for measuring DO. The entire analysis takes less then 5 minutes per sample. All the reagents used in this method can be stored in small vials with serum stoppers; it requires far less glassware than the Winkler method, and hence, it can be transported in a small kit for field studies. This syringe method is much less expensive than a DO probe and DO meter. The small sample size is conducive to laboratory respiration bioassays and to measuring micro-stratification of DO in small bodies of water. Hence, the syringe technique is accurate, quick, and convenient for measuring dissolved oxygen.

ACKNOWLEDGEMENTS

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Table 1. Dissolved Oxygen Readings for Ten Water Samples Using 3 Techniques

Sample Number	Syringe Method[a]	Winkler Method[a]	Probe Method[a]
1	0.7	0.9	*
2	0.4	0.8	*
3	0.5	0.9	*
4	0.6	0.7	*
5	1.8	1.9	2.1
6	4.7	4.8	4.9
7	4.3	4.3	4.3
8	7.5	7.6	7.8
9	7.7	8.0	8.1
10	9.7	9.6	9.9

[a]measured in parts per million (ppm)
*test not performed

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A MICROCOMPUTER SIMULATION OF THE INVERSION VIBRATION OF THE AMMONIA MOLECULE

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ABSTRACT

An algorithm is presented for computing the bond angles in ammonia in terms of the inversion energy barrier. This algorithm has been implemented on a microcomputer and its accompanying graphics printer to show perspective structures of the inverting molecule at various bond angles. A complete program listing and user instructions are presented.

INTRODUCTION

An enormously powerful and versatile generation of microcomputers is available for teaching and research purposes. These machines include "pocket" computers with impressive computational and graphics capability. In the course of carrying out computations of molecular structure and conformation, it became desirable to relate the energy of pyramidal (C_{3v}) molecules to the actual configuration as inversion occurs and to show these configurations graphically. A pocket computer has been used for this work and we present here the details of the algorithm and the implementation of the program in BASIC.

PRINCIPLES

The representation of a molecular potential energy function as a parabola is well known (King, 1964). In the case of the inversion vibration (ν_2) of pyramidal molecules like NH_3, there is a barrier to the inversion which is related to the bond angle. For NH_3, the inversion barrier is 2020 cm^{-1} (Hollas, 1982) and the normal bond angle, HNH, is 107.3° (DeKock and Gray, 1980). Therefore, when the bond angle is 120° (planar D_{3h} structure where the angle expansion is 12.7°) the energy of the configuration is 2020 cm^{-1}. The potential energy curve is shown in Figure 1. For the present computation, we have assumed that the potential energy for compression of the bond angle by 12.7° would also require an energy of 2020 cm^{-1} so

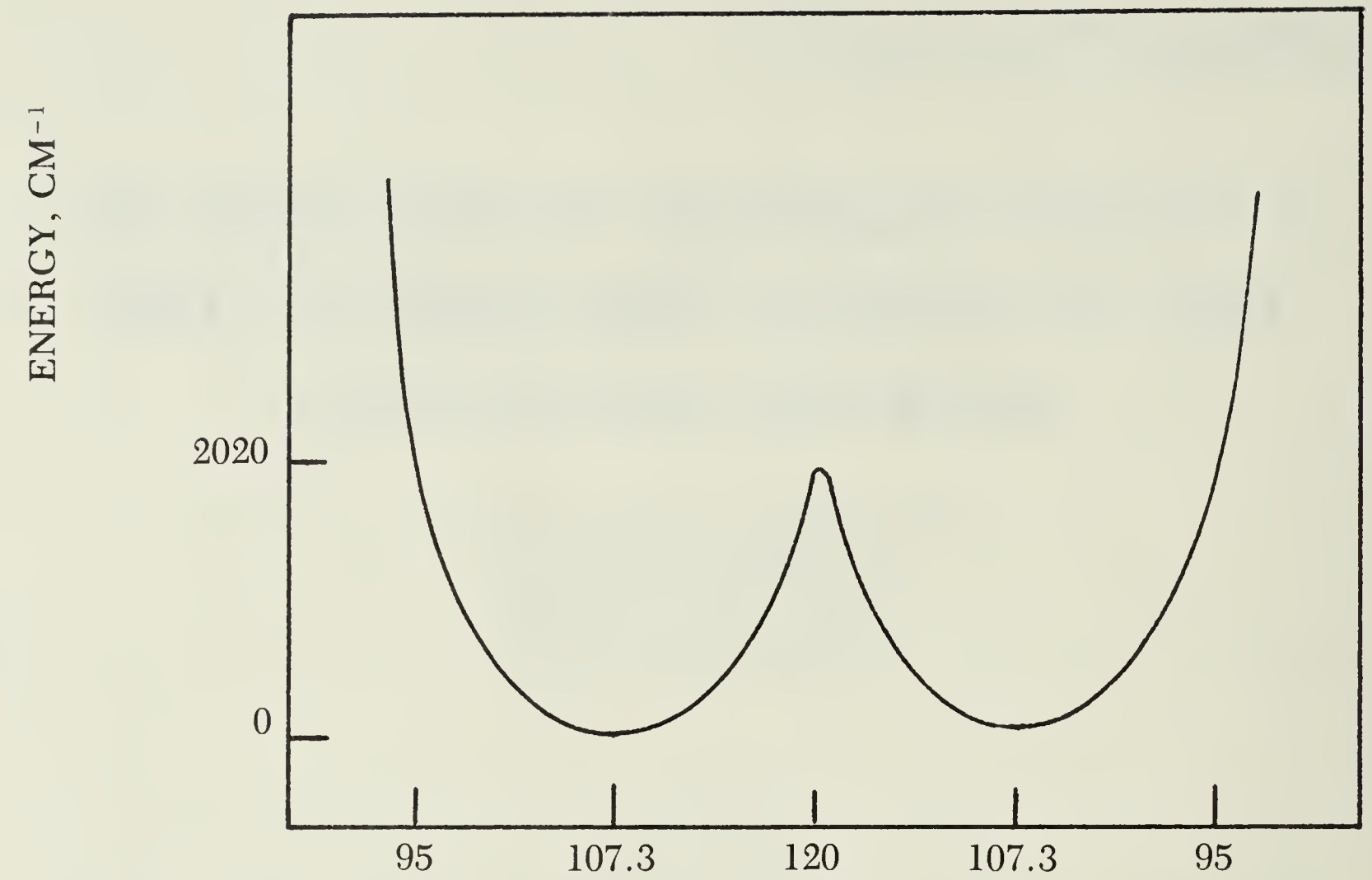

Fig. 1. Potential energy curve for the inversion of NH_3.

that each potential well is symmetrical with respect to increase or decrease of the HNH bond angle. Thus, the energy is assumed to be 2020 cm^{-1} at bond angles of 120 and 95 and to be 0 cm^{-1} at 107.3. Using the energies at these three bond angles, the parabolic relationship between energy and bond angle was established in order to calculate the energy at intermediate bond angles. A pocket computer programmed in BASIC was used to compute the energy and to draw the molecule at the desired bond angles.

ALGORITHM

Computation of the conformational energy of NH_3 at several bond angles was carried out and the graphical representation of each structure was drawn using a Radio Shack PC-2 pocket computer with a graphics plotter. At each bond angle, the x, y, and z-coordinates of each atom are calculated. Then, the horizontal and vertical angles between these coordinates and a fixed "eye" point and a "focus" point are calculated. These angles are then projected through a plane to yield a series of (x,y) points which are then plotted by the plotter. After the NH_3 molecule is drawn, the energy of the molecule at that bond angle is calculated using the parabolic approximation as the potential function. Finally, the HNH bond angle is incremented (or decremented) depending on the current motion and the process continues until the completed cycle of the vibration is complete. In running the program, the normal bond angle (NA) and the barrier energy (BE) are included in lines 100 and 110. These parameters may be changed at the user's discretion thus making the program adaptable to other pyramidal molecules. Also, the bond angle increment (BI) is specified in line 120. The starting value for the current bond angle (BA) is specified in line 130. A complete listing of the program in BASIC and a data dictionary are shown in the Appendix.

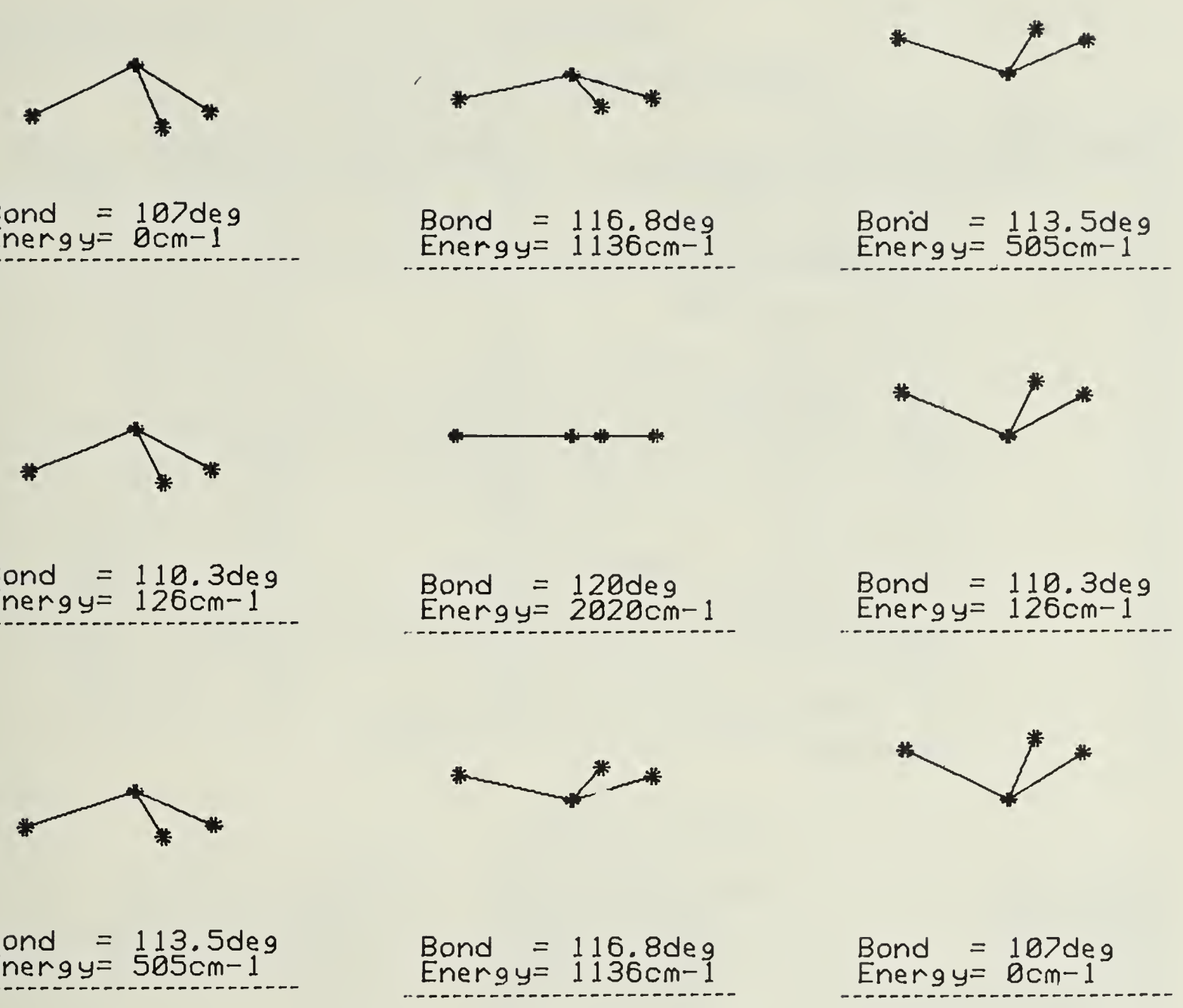

Fig. 2. Stages in a complete vibration of NH_3.

RESULTS AND DISCUSSION

Application of the program to the simulation of the inversion vibration of NH_3 produces the series of diagrams shown in Figure 2. The number of drawings produced to show a complete vibration can be varied by the program user. Therefore, in creating a motion effect, the number of drawings could be quite large with small changes in bond angle between each drawing. It is clear that the graphics capability of the pocket computer enables it to be a useful tool in showing molecular vibrations when suitable software is available. Certainly the production of perspective drawings, not just images on a display, showing the details of a molecular vibration in a "stop action" mode is of considerable heuristic value. We are currently developing other programs for using microcomputers to obtain a variety of molecular parameters and to show energy and structure relationships for both teaching and research applications.

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APPENDIX

PROGRAM DATA DICTIONARY

Name (DIM)	Description	Name (DIM)	Description
A	Atom ray angle	LL	Bond length
A (NP,1)	Atom horiz. angle	LT (NP)	Line type array
A (NP,2)	Atom vert. angle	L1	Loop counter 1
BA	H-N-H bond angle	L2	Loop counter 2
BE	Barrier energy	NA	Normal angle
BI	Angle increment	NP	No. XYZ pts.
DF	Dist. to focus pt.	P (NP,3)	Atom XYZ coord.
EX	Eye X coord.	PD	Dist. to plane
EY	Eye Y coord.	PW	Width of plane
EZ	Eye Z coord.	PX	Plotter X coord.
FX	Focus X coord.	PY	Plotter Y coord.
FY	Focus Y coord.	TA	Temporary angle
FZ	Focus Z coord.	VA	Vert. focus ang.
HA	Horiz. focus angle	VM	Vector magnifier
LA	Leg angle		

PROGRAM LISTING

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1ØØ:NA=1Ø7
11Ø:BE=2Ø2Ø
12Ø:BI=3.25
13Ø:BA=1Ø7
14Ø:DEGREE :GRAPH
    :GLCURSOR (1Ø8
    ,1Ø8):SORGN :
    CSIZE 2
15Ø:DIM P(99,3),A(
    99,2),LT(99):N
    P=1Ø
16Ø:EX=1:EY=1:EZ=2
   :PD=1:PW=.5:VM
    =216/PW:LL=1:N
    P=6
17Ø:LINE (-1Ø7,1Ø8
    )-(1Ø8,1Ø8),3,
    Ø
18Ø:FX=5:FY=5:FZ=2
19Ø:IF BA=16ØLET B
    I=BI*-1
2ØØ:IF BA=8ØLET BI
    =BI*-1
21Ø:TA=BA:IF BA>12
    ØLET TA=24Ø-BA
22Ø:LA=ASN (TA/12Ø
    ):IF BA>12ØLET
    LA=18Ø-LA
23Ø:P(1,1)=FX:P(1,
    2)=FY:P(1,3)=F
    Z:LT(1)=9
24Ø:P(2,1)=FX+SIN
    LA*COS Ø*LL:P(
    2,2)=FY+SIN LA
    *SIN Ø*LL:P(2,
    3)=FZ-COS LA*L
    L:LT(2)=Ø
25Ø:P(3,1)=FZ:P(3,
    2)=FY:P(3,3)=F
    Z:LT(3)=9
26Ø:P(4,1)=FX+SIN
    LA*COS 12Ø*LL:
    P(4,2)=FY+SIN
    LA*SIN 12Ø*LL:
    P(4,3)=FZ-COS
    LA*LL:LT(4)=Ø
27Ø:P(5,1)=FX:P(5,
    2)=FY:P(5,3)=F
    Z:LT(5)=9
28Ø:P(6,1)=FX+SIN
    LA*COS 24Ø*LL:
    P(6,2)=FY+SIN
    LA*SIN 24Ø*LL:
    P(6,3)=FZ-COS
    LA*LL:LT(6)=Ø
29Ø:FX=FX-EX:FY=FY
    -EY:FZ=FZ-EZ
3ØØ:FOR L1=1TO NP
31Ø:P(L1,1)=P(L1,1
    )-EX
32Ø:P(L1,2)=P(L1,2
    )-EY
33Ø:P(L1,3)=P(L1,3
    )-EZ
34Ø:NEXT L1
35Ø:VA=ATN (FZ/SQR
    (FX^2+FY^2))
36Ø:HA=ATN (FY/FX)
37Ø:DF=SQR (FX^2+F
    Y^2+FZ^2)
38Ø:FOR L1=1TO NP
39Ø:A(L1,1)=ATN (P
    (L1,3)/SQR (P(
    L1,1)^2+P(L1,2
    )^2))-VA
4ØØ:A(L1,2)=ATN (P
    (L1,2)/P(L1,1)
    )-HA
41Ø:A(L1,2)=ATN (
    TAN A(L1,2)/(D
    F/SQR (P(L1,1)
    ^2+P(L1,2)^2))
    )
42Ø:NEXT L1
43Ø:FOR L1=1TO NP
44Ø:PY=+PD*TAN (A(
    L1,1))*VM
45Ø:PX=-PD*TAN (A(
    L1,2))*VM
46Ø:LINE -(PX,PY),
    LT(L1)
47Ø:IF L1=3OR L1=5
    THEN Ø52Ø
48Ø:FOR L2=1TO 1Ø
49Ø:A=36*L2
5ØØ:LINE (PX+COS A
    *5,PY+SIN A*5)
    -(PX,PY),Ø
51Ø:NEXT L2
52Ø:NEXT L1
53Ø:GLCURSOR (-1Ø8
    ,-1ØØ)
54Ø:TA=BA:IF BA>12
    ØLET TA=24Ø-BA
55Ø:LPRINT "Bond
     =";INT (TA*1Ø
    +.5)/1Ø;"deg"
56Ø:GLCURSOR (-1Ø8
    ,-116):LPRINT
    " Energy=";INT
    ((BE/(12Ø-NA)^
    2)*(TA-NA)^2+.
    5);"cm-1"
57Ø:GLCURSOR (Ø,-2
    32):SORGN
58Ø:BA=BA+BI
59Ø:GOTO 17Ø
```

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THE MAMMALS OF IROQUOIS COUNTY CONSERVATION AREA*

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ABSTRACT

A survey of the mammals of Iroquois County Conservation Area was conducted on September 13-17, 1982. A checklist of mammals known to occur and those which may occur was developed. Results from small mammal trapping in ten different plant communities indicated that the sedge meadow was a highly productive community having the greatest diversity and among the highest trap success. No endangered or threatened species were found. The red squirrel, *Tamiasciurus hudsonicus*, is an exceptional species which occurs at the site.

INTRODUCTION

Iroquois County Conservation Area is a 1,920 acre tract located 2 miles north and 3 miles west of Beaverville in Sections 22, 23 and 24, T29N, R11W in extreme northeastern Iroquois County. It is a large, diverse area with high quality natural communities which are limited in occurrence in Illinois. These include sedge meadow, marsh, shrub prairie, dry sand savanna, wet-mesic prairie, dry-mesic sand prairie, dry-mesic sand savanna and flatwoods (INAI files).

Little is known of the presence and/or abundance of the mammals which inhabit this outstanding example of the Kankakee Sand Area. The objectives of the project were to 1) inventory the mammals associated with each community type/habitat, 2) establish a checklist of mammals known to occur on the site, 3) determine if any endangered or threatened mammals occur on the site and 4) determine the uniqueness, in terms of mammaliam fauna, of this site.

*Send reprint request to second author.

METHODS

Trapping stations for small mammals were placed 8 meters apart along transects with three Museum Special snap traps, baited with rolled oats, peanut butter and bacon grease, per station. Traps were checked for four consecutive nights on 13-17 September 1982. Small mammals captured were placed in plastic bags, labelled (date, location, habitat type) and placed on ice for later identification and preparation as study specimens.

Presence of other mammals was evaluated by direct observation of the animal and/or its sign and interviews with persons who are knowledgeable of the site.

An effort was made to establish transects in each representative natural community, however, because the dry sand savanna and dry-mesic sand savanna could not be differentiated on the ground, the latter community was not sampled. In addition, the following man-made or disturbed habitats were sampled: old field, pine plantation, and creek bank. The number of stations in each natural community/habitat varied due to size of natural community/habitat, level of disturbance and anticipated future developments/disturbances to the community.

RESULTS AND DISCUSSION

Trapping effort included 990 trap-nights. Trap success, reported as captures per 100 trap-nights, was determined for each natural community/habitat (Table 1) and averaged 4.24 overall. Trap success was greatest in the old field, wet-mesic prairie, marsh and sedge meadow. The dry sand savanna yielded no specimens throughout the duration of the study. Each station in the dry sand savanna was stripped of the bait each day, probably due to insect activity. The trap success in the pine plantation also suffered from loss of bait. But, unlike the sand savanna, most of the traps were tripped every night. A larger animal, possibly a domestic dog or squirrel, may have been responsible for tripping the traps and consuming the bait. This problem was not noted in any of the other natural community/habitats.

The sampling yielded 42 specimens representing five species: masked shrew, *Sorex cinereus* (11); short-tailed shrew, *Blarina brevicauda* (11); white-footed mouse, *Peromyscus leucopus* (3); meadow vole, *Microtus pennsylvanicus* (15); and meadow jumping mouse, *Zapus hudsonius* (2). The number of individuals and species captured in each natural community/habitat is depicted in Table 1. The greatest number of individuals and species was captured in the sedge meadow community. The number of shrew captures was noteworthy as pitfalls are reportedly more effective in capturing insectivores than snap traps (Rose and McKean, 1980; Williams and Braun, in press). The meadow vole was captured in five habitat types and was the most abundant species at the site representing 36% of the animals captured (Table 1). The masked shrew and short-tailed shrew were also numerous being captured in six habitat types collectively and together comprised 52 percent of the animals captured. Two meadow jumping mice were captured in grassy habitats during the study. Low capture rates of this species are not unusual because, although statewide in occurrence, it is not abundant (Hoffmeister and Mohr, 1957). The white-footed mouse was captured only in the pine plantation. This species absence from the samples in other natural communities/habitats is due to the near absence of its preferred cover; fallen trees, decaying logs, and brush piles (Darrow and Hallett, 1980).

In addition to the species which were trapped, six others were noted by direct observation of the animal or its sign. These species include the raccoon, *Procyon lotor* (creek); woodchuck, *Marmota monax* (edge of flatwoods); eastern fox squirrel, *Sciurus niger* (flatwoods); red squirrel, *Tamiasciurus hudsonicus* (flatwoods); muskrat, *Ondatra zibethicus* (man-made potholes); and white-tailed deer, *Odocoileus virginianus* (old field, flatwoods). Most noteworthy among these is the red squirrel observation. This animal was shot by a hunter who mistook it for a small fox squirrel. The unlawful harvest of red squirrels occasionally occurs during the public hunting season (personal communication, 1982, Frank Snow, Illinois Department of Conservation, Beaverville, Illinois).

Based on interviews with persons knowledgeable of the area, other species are known to occur at the site (Table 2). The abundance of small mammals undoubtedly provides a staple food source for the larger carnivorous mammals which have been observed. Other mammals may also occur but remain undetected or were not adequately sampled (Table 3). Among these is the Indiana bat, *Myotis sodalis*, a federal and state endangered species which may forage and roost in the area during the summer months. A total of 40 or more of the 60 mammal species native and naturalized of Illinois may occur at Iroquois County Conservation Area.

SUMMARY

Each natural community/habitat was sampled and a checklist of mammals known to occur at the site developed. Additional sampling is needed to document all species which may occur there. The only mammal listed as threatened or endangered by the Endangered Species Protection Board which may be found at the site is the Indiana bat. Most other species, except for the red squirrel, are not exceptional in their occurrence or habitat utilization. Little is known of the population status, taxonomy, or life history of the red squirrel in Illinois. Unlawful harvest illustrates the need for greater public/hunter education. Further study and public education are needed to ensure a continued and healthy population of this exceptional species at the site.

ACKNOWLEDGEMENTS

We wish to thank the site personnel for access to trapping areas and assistance while on the site. Thanks to Carl Becker and Vic Diersing who critically reviewed the manuscript.

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Table 1. Number of individuals and species of small mammals captured within each natural community/habitat at Iroquois County Conservation Area, Iroquois County, Illinois, 13-17 September 1982.

	NATURAL COMMUNITY/HABITAT											
SPECIES	Sedge Meadow	Marsh	Shrub Prairie	Dry Sand Savanna	Wet-Mesic Prairie	Dry-Mesic Sand Prairie	Flat-woods	Tree Planta-tion	Old Field	Creek	Total	Per Cent
Masked shrew	4		3			1	3				11	26
Short-tailed shrew	4				3		1		3		11	26
White-footed mouse								3			3	7
Meadow vole	5	3	1		4	2					15	36
Meadow jumping mouse	1				1						2	5
TOTAL INDIVIDUALS	14	3	4	0	8	3	4	3	3	0	42	
TOTAL SPECIES	4	1	2	0	3	2	2	1	1	0	5	
NO. OF TRAP NIGHTS	210	36	120	120	90	120	120	120	27	27	990	
TRAP SUCCESS IN PERCENT	6.67	8.33	3.33	0	8.89	2.5	3.33	2.5	11.11	0.0	4.24	

Table 2. Checklist of Native Mammals Known to Occur at Iroquois County Conservation Area

SCIENTIFIC NAME	COMMON NAME	DOCUMENTATION*
Didelphis virginiana	Opossum	RO
Scalopus aquaticus	Eastern mole	RO
Sorex cinereus	Masked shrew	MS
Blarina brevicauda	Short-tailed shrew	MS
Procyon lotor	Raccoon	VS, RO
Mustela vison	Mink	RO
Mephitis mephitis	Striped skunk	RO
Taxidea taxus	Badger (adjacent areas)	RO
Vulpes vulpes	Red fox	RO
Urocyon cinereoargenteus	Gray fox	RO
Canis latrans	Coyote	RO
Marmota monax	Woodchuck	DO, RO
Spermophilus tridecemlineatus	Thirteen-lined ground squirrel	RO
Sciurus niger	Eastern fox squirrel	DO, RO
Tamiasciurus hudsonicus	Red squirrel	DO, RO
Glaucomys volans	Southern flying squirrel	RO
Geomys bursarius	Plains pocket gopher	RO
Castor canadensis	Beaver	RO
Peromyscus leucopus	White-footed mouse	MS
Microtus pennsylvanicus	Meadow vole	MS
Ondatra zibethicus	Muskrat	VS, RO
Zapus hudsonius	Meadow jumping mouse	MS
Sylvilagus floridanus	Eastern cottontail	RO
Odocoileus virginianus	White-tailed deer	VS, DO, RO

*
MS = trapped in museum special during study
VS = visual observation of sign during study
DO = direct observation of animal during study
RO = reliable observer reported occurrence

Nomenclature follows Jones et al., 1982.

Table 3. Mammals Which May Occur at Iroquois County Conservation Area

SCIENTIFIC NAME	COMMON NAME
Cryptotis parva	Least shrew
Myotis lucifugus	Little brown bat
Myotis keenii	Keen's bat
Myotis sodalis	Indiana bat
Lasionycteris noctivagans	Silver-haired bat
Pipistrellus subflavus	Eastern pipistrel
Eptesicus fuscus	Big brown bat
Lasiurus cinereus	Hoary bat
Lasiurus borealis	Red bat
Mustela nivalis	Least weasel
Mustela frenata	Long-tailed weasel
Spermophilus franklinii	Franklin's ground squirrel
Reithrodontomys megalotis	Western harvest mouse
Peromyscus maniculatus	Deer mouse
Microtus pinetorum	Pine vole

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OCCURRENCE OF THE NAUTILOID GENUS *FOORDICERAS* IN THE PENNSYLVANIAN PERIOD OF NORTH AMERICA

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ABSTRACT

A specimen identified as *Foordiceras* sp. nov. is described. This is the first reported occurrence of the genus *Foordiceras* in North America and extends the stratigraphic range of the genus into the Pennsylvanian Period.

INTRODUCTION

Previously species of the genus *Foordiceras* were known only from the Permian of Europe, Asia and the East Indies (Kummel, 1953, 1964). The present paper reports the first species of the genus known from North America and extends the stratigraphic range of the genus into the Pennsylvanian Period.

LOCATION AND STRATIGRAPHY

The specimen was collected at the type section of the Shumway Cyclothem (Mattoon Formation, Upper Pennsylvanian) located 2 miles east of Shumway, Effingham County, Illinois (SE1/4 SE1/4 SW1/4, sce. 26, T9N, R5E, Effingham Quadrangle). Kosanke *et al.* (1960) described the stratigraphic section at this locality. The specimen was collected from the lower bed of the Shumway limestone. Eleven species of coiled nautiloids have been reported from the unit (Tucker, 1979).

Address Reprint Requests to G.L. Paukstis.

SYSTEMATIC PALEONTOLOGY
Family KONINCKIOCERATIDAE Hyatt and Zittel, 1900
Genus FOORDICERAS Hyatt, 1893

Diagnosis. Kummel (1964) adequately diagnoses *Foordiceras* as involute nautilicones with moderately broad, deep umbilicus; trapezoidal whorl section with broad venter, convex lateral areas that slope dorsally, ventral shoulders rounded, umbilical shoulders more broadly rounded, umbilical wall broad and steep, flanks with transversely elongated nodes on ventral shoulders that disappear by the middle of the lateral area; sutures slightly sinuous, position of the siphuncle unknown.

Remarks. Kummel (1953) restricted *Foordiceras* to include species whose conchs are trapezoidal in whorl section and whose flanks slope down from venter regularly to the unbilical suture showing only a slight curve without forming a distinct umbilical wall or shoulder. He (Kummel, 1953) thus excluded the large number of North American Permian nautiloids that Miller and Youngquist (1949) had previously included in the genus. Those species all have depressed subquadratic whorl sections and well developed umbilical shoulders that result in distinct lateral areas and umbilical walls. The species described below has a relatively distinct umbilical shoulder but only on the test. If the cross section of the internal mold is compared to the cross section of *Foordiceras goliathum* (Waagen) which is also based on an internal mold the similarity is striking. The tapering ribs which die out before the umbilical shoulder is reached confirms the identification of the Shumway specimen as a species of *Foordiceras*.

Material. This species is represented by one poorly preserved specimen (PE 28369) which has been deposited in the collection of the Field Museum of Natural History, Chicago (Fig. 1).

Diagnosis. A species of *Foordiceras* that is slightly depressed (W/H = 1.4); distinct umbilical shoulders on the exterior of the shell but rounded umbilical shoulders on the internal mold; convex lateral areas between transversely elongate tapering ribs.

Description. The large moderately evolute shell is estimated to have reached 170 mm in total diameter with the umbilicus making up about one-third of the total. At its adoral end the specimen is estimated to have been 90 mm wide and 64 mm high. The cross section of the test and the internal mold is different due to thickening of the test. The test is subtrapezoidal in cross section having slightly convex ventral and lateral areas, rounded ventrolateral shoulders, distinct angular umbilical shoulders and flat umbilical walls that meet the sides at an angle of about 135 degrees. The shell is widest slightly dorsad of the ventrolateral shoulders. At its adoral end the venter is estimated to be 76 mm wide, the lateral area is 30 mm wide and the umbilical wall is 34 mm wide. The dorsum was not preserved intact but is estimated to have been about 28 mm wide. The cross section of the internal mold is much less angular than that of the test. The venter is broadly arched and rounds into the convex sides which cannot be distinguished from the umbilical walls on the internal mold. The test is very thick. At the adoral end of the septum it is 7 mm thick at the umbilical shoulder, 6 mm thick at the ventrolateral shoulder, 2 mm thick along the umbilical wall and 4 mm thick along the sides. The specimen appears to be a portion of a body chamber, at least it is not septate. The test is ornamented by transversely elongated ribs that are widest at their ventrolateral ends then taper towards the dorsal end. They disappear before reaching the umbilical

shoulder of the shell. The two adoral ribs are 35 mm apart as measured from the crest of one rib to the crest of the next. The adapical portion of the specimen is badly weathered and the ribs are nearly destroyed. The ventrolateral ends of the two best preserved ribs do not appear to have been elevated into distinct nodes. Camerae, sutures, siphuncle and the inner whorls were not preserved.

Comparison. Although the shell is less depressed than any of the Eurasian congeners and appears to represent an undescribed species, too little is known of its morphology to allow unequivocal identification of the species. Consequently it would be unwise to base a new nominal species on this one specimen. Among North American Paleozoic nautiloids only *Temnocheilus* sp. (Miller and Youngquist, 1949, Pl. 59, figs. 1, 2) is remotely similar to *Foordiceras* sp. It too has an internal mold with a rounded cross section. However, *Temnocheilus* sp. lacks lateral ribs and has well developed spine-like ventrolateral nodes suggesting that Miller and Youngquist (1949) were correct in placing it in *Temnocheilus* rather than *Foordiceras*.

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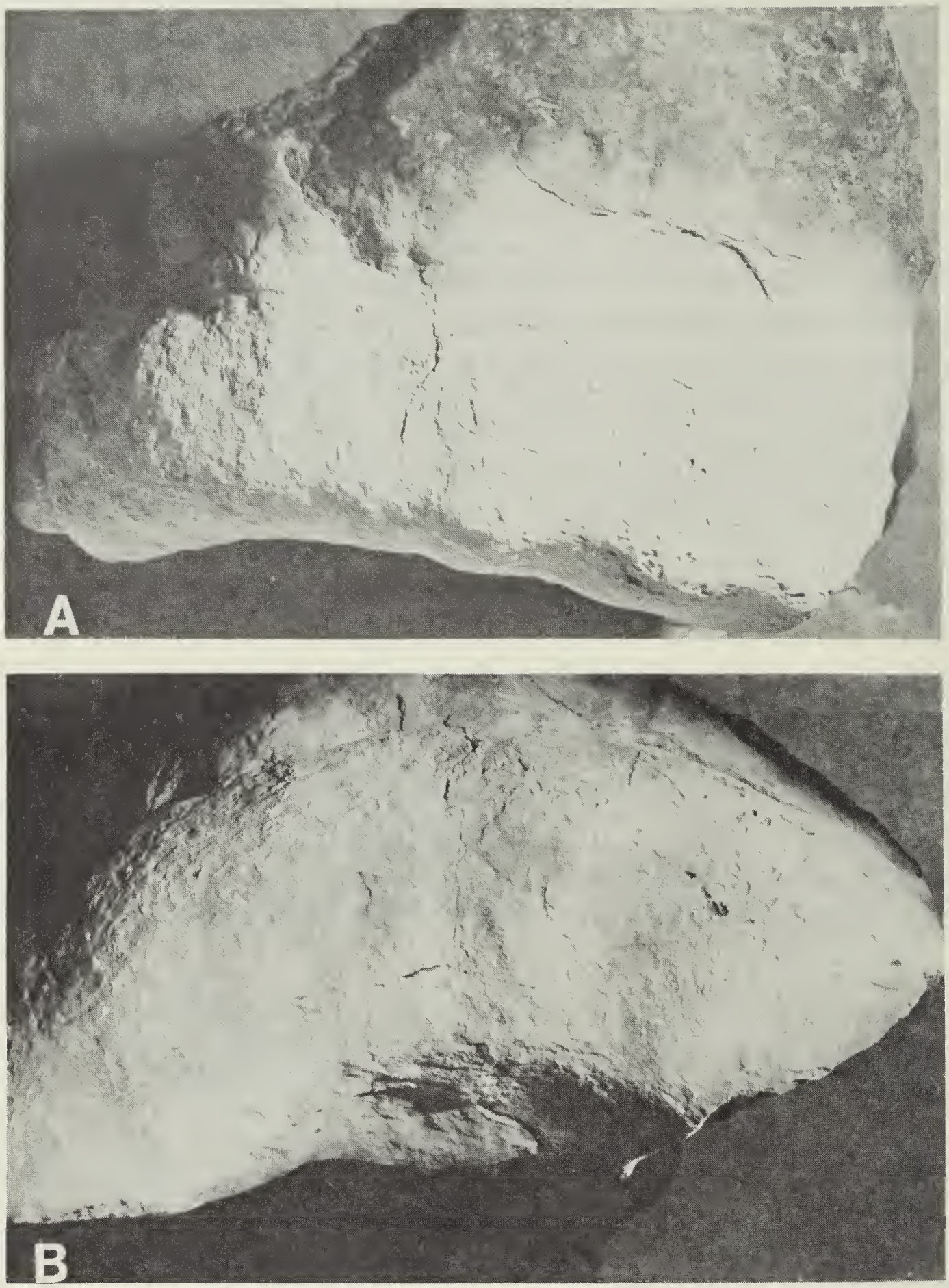

Fig. 1. *Foordiceras* sp. nov. (PE 28369), ventral (A) and lateral (B) aspects of the specimen.

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PARAGONIMUS KELLICOTTI WARD, 1908 (TREMATODA:PARAGONIMIDAE) FROM RED AND GRAY FOXES OF SOUTHERN ILLINOIS

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ABSTRACT

Paragonimus kellicotti was observed in the lungs of 7 (1.2%) of 543 *Urocyon cinereoargenteus* taken in Jackson, Johnson, Union, and Williamson counties, southern Illinois, between November, 1959 and October, 1963 and in the lungs of 4 (2.4%) of 165 *Vulpes vulpes* taken in Jackson, Union, and Williamson counties between November, 1960 and February, 1964.

INTRODUCTION

In conjunction with examination of stomach and intestional contents of a large number of *Vulpes vulpes* and *Urocyon cinereoargenteus* to ascertain their food habits, there was opportunity to examine lung tissues for the digenetic fluke, *Paragonimus kellicotti* Ward, 1908.

MATERIALS AND METHODS

One hundred and sixty-five red foxes were either shot or trapped in Union, Williamson, and Jackson counties, southern Illinois, between November, 1960 and February, 1964. Likewise, 543 gray foxes were similarly taken in Union, Williamson, Johnson, and Jackson counties between November, 1959 and October, 1963. The lungs of each animal were removed and examined for encysted flukes. Detected flukes were fixed in alcohol-formalin-acetic acid (AFA), stained with either Harris' or Delafield's hematoxylin and mounted in Canada balsam.

RESULTS AND DISCUSSION

Paragonimus kellicotti was observed in the lungs of 7 (1.2%) of 543 *U. cinereoargenteus* and 4 (2.4%) of 165 *V. vulpes*. Most foxes had but a single cyst contain-

ing two sexually mature flukes confined to a single lobe of the lung. A few animals had cysts containing three to four flukes.

While this parasite has been reported from cats, dogs, domestic swine, muskrats, bobcats, opossum, striped skunks, goats, raccoons, red foxes, minks and human beings in North America, on the basis of the frequency of natural infections, minks are believed to be the natural host. Foxes are unusual hosts for this fluke. It was first reported from *Vulpes vulpes* in North America by Erickson (1944) who detected 31 *P. kellicotti* from a red fox collected near Redwood Falls, Minnesota. A later identification was recorded from *V. vulpes* in Michigan (Stuht and Youatt, 1972). To my knowledge, this fluke has not been reported from *U. cinereoargenteus*.

According to Ameel (1934), mammals become infected either by ingesting cray fish containing the metacercarial stage or by ingesting carrier host infected with immature adult flukes. Infections in this investigation were probably acquired by ingesting contaminated crayfishes, as these remains were detected in fox stomachs.

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WOODY VEGETATION AT BURGNER ACRES, EAST-CENTRAL ILLINOIS: COMPOSITION AND CHANGES SINCE 1964

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ABSTRACT

A comparative study of woody vegetation changes on Burgner Acres over the past 18 years is reported. Presently 30 arborescent species are found in the woodlot with white ash maintaining its position as first in Importance Value, hackberry has increased from fourth to second in importance, while elm, shagbark hickory, and black walnut show little change in relative values. Also, a decrease in elm mortality and a decrease in the importance of red haw has resulted in an increase in the ranking of white oak. Sugar maple has become well established in parts of the woodlot and will undoubtedly increase due to its superior gap phase replacement potential.

INTRODUCTION

Burgner Acres is a 10 acre woodlot located approximately 8 miles northwest of Charleston, Illinois. It was donated to Eastern Illinois University in January 1955 by Mrs. Helen Burgner Douglas as a memorial to her father and grandparents who were pioneer settlers in the county. Since 1955 it has been maintained undisturbed except for a footpath, and has been utilized for research and educational purposes. Shortly after the woodlot was acquired, six permanent quadrats were established (Henderson and Damann, 1966), and in 1962 six line transects were run by an ecology class to determine woody composition. In 1964 a complete survey of the woody vegetation was undertaken (Blackmore and Ebinger, 1967) allowing for the analysis of even the less important tree species. This paper is a follow up to that study to determine woody vegetation changes over the past 18 years.

DESCRIPTION OF THE WOODLOT

Burgner Acres is located in the Grand Prairie Division of Illinois (Schwegman, 1973) three miles north of the Shelbyville Moraine in Coles County, Illinois (SW¼ NE¼ Sec 1 T12N R8E). It is traversed by Sycamore Creek and has a gently rolling

topography with a maximum difference in elevation of about 25 feet. Sycamore Creek divides the woodlot into three well defined study areas (Henderson and Damann, 1966). Area A, at the north edge of the woodlot, slopes gradually toward Sycamore Creek. Prior to acquisition of the woodlot by Eastern Illinois University, this area was frequently mowed. Area B is a somewhat less disturbed moist area which slopes to a second loop of the creek. Area C is a partially disturbed higher and drier area beyond the second loop of the creek. Two soil types are present in the woodlot (Yellow-Gray Silt Loam, Yellow Silt Loam). Both are classified as upland timber soils (Smith, et al., 1929).

MATERIALS AND METHODS

To facilitate direct analysis of vegetation changes the method employed was that of Blackmore and Ebinger (1967). The entire woodlot was staked off into 50 feet square quadrats and the number, size, and species of all trees four inches dbh and over were recorded. Relative density, relative dominance, relative frequency and Importance Value of each species were then calculated using the procedures outlines by Blackmore and Ebinger (1967). These values were calculated not only for the entire woodlot, but also for each of the three areas outlined in the description of the woodlot. Dead standing trees were measured and identified when possible, but only dead elms were used in the calculations because they comprise a relatively large part of the stand.

One set of nested, circular plots 1/100 and 1/1000 or an acre in size was randomly located in each 50 foot square quadrat. Saplings (1-4 inches dbh) were tallied on the larger and seedlings on the smaller plots. The seedlings were separated into those under one foot in height, and those over one foot in height but less than one inch dbh. The nomenclature used follows Jones (1963).

RESULTS

Of the 30 arborescent species encountered on the woodlot, 7 are understory trees. These species, along with their density and frequency by size classes, are shown in Table 1. Also, the 12 leading species, with their relative values, average diameters and number of individuals per acre in broad diameter classes are shown in Table 2.

Of the arborescent species listed in Table 2, white ash ranks first in Importance Value, having the highest relative frequency, relative density, and relative dominance. It predominates in both the 4-6 and 7-12 inch diameter classes, firmly establishing its position as first in importance. Hackberry, which is second in importance, ranks close behind white ash in both relative frequency and relative density but has less basal area. The large number of individuals of this species in the 4-6 and 7-12 inch diameter classes suggests that it will maintain its position of codominance with white ash.

As no attempt was made to distinquish slippery elm and American elm in the previous study (Blackmore and Ebinger, 1967), they were combined in the present study. In the woodlot, elm is third in number of individuals per acre in the 4-6 inch diameter class and in total individuals, as well as third in Importance Value. Presently dead elms account for 14% of all standing elms. This mortality, which is due to phloem necrosis and Dutch elm disease, effectively limits the importance of

this species. If values for living and dead elm are summed, its importance slightly exceeds that of hackberry.

Black walnut, as fourth in importance, only slightly exceeds shagbark hickory which is fifth in importance. This is due mainly to the large size of individual trees. Shagbark hickory ranks higher than walnut in trees per acre in the smaller diameter classes, and will probably surpass walnut in importance as these individuals mature.

White oak and mockernut hickory are sixth and seventh in importance respectively, primarily due to the large size of individual trees. Bitternut hickory and shingle oak are present also in larger diameter classes, but their low density results in a low importance value. Red haw and black cherry are present in the smaller diameter classes, but their low basal area and relative sparseness results in a low importance.

DISCUSSION

Considerable change has taken place in the woodlot since the original survey in 1964 (Blackmore and Ebinger, 1967). A major change is the number of individuals per acre; averaging 143 in 1964 and presently averaging 194 stems per acre (Table 2). Most of this increase occurs in the 4-6 inch diameter class (87.6 in 1964 to 113.1 in 1982), and in the 7-12 inch diameter class (28.6 in 1964 to 54.7 in 1982). Another difference is the change in Importance Value and ranking of some of the species, both in the entire woodlot, as well as in the three separate study areas (Tables 2 & 3).

White ash maintains its position as first in importance in the entire woodlot. It has more than doubled in individuals per acre (22.4 in 1964 to 48.0 in 1982), and while it has increased in all three areas, its major increase has occurred in Area A. In this area it has increased from eighth to a present fourth in importance. This apparent lag in reproduction is possibly due to an inability of ash to germinate and compete in the years subsequent to the area having been mowed and grazed. Adequate germination and growth possibly occurred only after there was an accumulation of nutrients provided by leaf litter (Fowells, 1965).

Hackberry has increased from fourth to second in importance. Its present position as second in individuals per acre suggests that it will continue as second in importance for a long period of time. This substantial increase has displaced elm to third in importance. Elm has increased in all diameter classes, but hackberry has increased at a greater rate, consequently the ranking change. Elm mortality has decreased more than 50%, and the diameter of dead elm has decreased to an average of 6.9 inches (13.5 inches in 1964).

Black walnut, which is fourth in importance, has increased in relative dominance while experiencing a decrease in relative density. This species is not reproducing well in the woodlot and will eventually decrease to a lower importance as the larger individuals die. Hickories will probably exhibit this same pattern, though shagbark hickory will probably remain important as it is exhibiting better recruitment from the seedling and sapling strata. Presently shagbark hickory has increased slightly in stems per acre, but the relative value of this increase is negligable when compared to the increase in the species ranked higher.

White oak has made a slight increase in stems per acre over the past 18 years, primarily in Area C. The increased importance of white oak is primarily due to

the decrease in previously more important species. One of these is red haw, in which the number of stems per acre has decreased to less than half of what was present in the original survey (16.6 in 1964 to 7.4 in 1982). This decrease, as predicted by Blackmore and Ebinger (1967), is largely a response to canopy closure.

Blackmore and Ebinger (1967) reported a large number of sugar maple seedlings and saplings on a portion of the slope to Sycamore Creek in Area C. Presently in Area C, sugar maple is represented by a total of 6.1 individuals per acre in the 4-6 inch and 7-12 inch diameter classes with an average diameter of 6.2 inches (Table 1). Its importance value of 8.0 ranks it as tenth in importance when only Area C is considered. The superior gap phase replacement potential of sugar maple and its rapid establishment in Area C suggests that it will spread throughout Area C, and possibly throughout the entire woodlot, as is occurring in Sargents Woods (Ebinger, 1968) and Baber Woods (McClain and Ebinger, 1968). The far future implications of this suggest that sugar maple could rise to codominance with white ash, hackberry, and elm. The composition of this woodlot would then closely resemble the composition of prairie groves (Boggess, 1964; Boggess and Bailey, 1964).

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Table 1. Density per acre and frequency of arborescent species by height or diameter class at Burgner Acres. The species symbols will be used to identify species in subsequent tables.

Scientific name	Common name		Height Class					Diameter Class			
			Density			Frequency %		1″-4″		4″ +	
			<1′	>1′<1″ dbh	Total	<1′	>1<1″ dbh	Density	Freq. %	Density	Freq. %
Fraxinus americana	White ash	WA	27	187	214	2.0	14.7	45	32.7	47.96	77
Ulmus sp.	Elm	E	53	660	713	4.7	29.3	150	57.3	37.17	74
Celtis occidentalis	Hackberry	H	40	747	787	2.7	40.7	165	62.0	42.29	69
Carya ovata	Shagbark hickory	SH	7	33	40	.7	2.7	15	11.3	14.51	42
Juglans nigra	Black walnut	BW	--	--	--	--	--	2	1.3	10.92	38
Crataegus mollis	Red haw	RH	7	20	27	.7	2.0	20	15.3	7.43	27
Ulmus sp. (daed)	Dead elm	DE	--	--	--	--	--	--	--	5.81	26
Carya tomentosa	Mockernut hickory	MH	7	20	27	.7	2.0	2	2.0	5.23	22
Quercus alba	White oak	WO	7	13	20	.7	1.3	1	.7	3.83	19
Carya cordiformis	Bitternut hickory	BH	20	80	100	1.3	7.3	10	9.3	4.19	15
Prunus serotina	Black cherry	BC	53	247	300	2.7	13.3	13	8.7	3.61	13
Gleditsia triacanthos	Honey Locust	HL	--	--	--	--	--	--	--	1.51	7
Cercis canadensis	Red bud	RB	--	--	--	--	--	3	3.3	1.63	6
Quercus imbricaria	Shingle oak	SO	--	7	7	--	.7	1	1.3	1.98	5
Maclura pomifera	Osage orange	OO	--	--	--	--	--	--	--	1.16	5
Acer saccharum	Sugar maple	SM	100	53	153	2.7	3.3	33	8.0	1.63	5
Quercus macrocarpa	Bur oak	BO	--	7	7	--	.7	5	4.7	.93	5
Carya glabra	Pignut hickory	PH	--	--	--	--	--	--	--	.24	1
Robinia pseudoacacia	Black locust	BL	--	--	--	--	--	--	--	.93	1
Platanus occidentialis	Sycamore	S	--	--	--	--	--	--	--	.46	1
Salix nigra	Black willow	Bl	--	--	--	--	--	--	--	.12	1
Quercus rubra	Red oak	RO	--	--	--	--	--	--	--	.23	1
Sassafras albidum	Sassafras	Sa	--	7	7	--	.7	--	--	.35	1
Acer negundo	Box elder	BE	--	--	--	--	--	--	--	.12	1
Tilia americana	Linden	L	--	13	13	--	1.3	1	.7	.58	1
Morus rubra	Red mulberry	RM	--	--	--	--	--	1	.7	--	--
Crataegus crusgalli	Cockspur thorn	CT	--	--	--	--	--	2	2.0	--	--
Malus ioensis	Iowa crabapple	IC	--	--	--	--	--	1	1.3	--	--
Viburnum prunifolium	Black haw	B	7	147	154	.7	10.0	11	6.7	--	--
Quercus muhlenbergii	Chinquapin oak	CO	--	7	7	--	.7	2	2.0	--	--
Euonymus atropurpureus	Wahoo	W	--	33	33	--	2.7	--	--	--	--
	Totals		328	2281	2609	--	--	483	--	194.82	--

Table 2. Diameter classes, average diameter, relative values, and importance values for the leading dominants at Burgner Acres. Also included is the importance values for these species from the 1964 survey and the amount of change from the present survey.

Species	Number of Trees per Acre by Diameter Class 4-6	7-12	13-24	25+	Total	Av. Diam.	Rel. Freq.	Rel. Den.	Rel. Dom.	I.V. 1982	I.V 1964	I.V Change
WA	30.4	12.9	3.5	1.2	48.0	7.6	16.6	24.6	20.5	61.7	43.2	+18.5
H	28.8	12.1	1.1	.3	42.3	6.7	14.9	21.7	12.2	48.8	28.3	+20.5
E	27.3	9.6	.2	--	37.1	6.2	16.0	19.1	8.3	43.4	35.5	+ 7.9
BW	1.4	3.1	5.6	.8	10.9	14.2	8.2	5.6	14.2	28.0	27.9	+ .1
SH	3.5	6.4	4.4	.2	14.5	11.1	9.1	7.4	11.4	27.9	32.0	- 4.1
WO	.8	.1	.9	2.0	3.8	21.8	4.1	2.0	11.6	17.7	17.5	+ .2
MH	.3	1.6	3.3	--	5.2	14.0	4.8	2.7	6.0	13.5	13.6	- .1
RH	6.8	.6	--	--	7.4	5.2	5.9	3.8	1.1	10.8	25.4	-14.6
DE	3.9	1.9	--	--	5.8	6.9	5.6	3.0	1.5	10.1	26.7	-16.6
BH	1.5	1.6	1.1	--	4.2	10.0	3.3	2.2	2.8	8.3	7.2	+ 1.1
BC	2.6	1.0	--	--	3.6	6.1	2.8	1.8	.8	5.4	3.9	+ 1.5
SO	1.0	.6	.4	--	2.0	9.0	1.2	1.0	1.1	3.3	2.2	+ 1.1
Others	4.8	3.2	1.3	.6	9.9	12.6	7.5	5.1	8.5	21.1	36.6	-15.5
	113.1	54.7	21.8	5.1	194.7	--	100.0	100.0	100.0	300.0	300.0	--

Table 3. Diameter classes, average diameters, relative values, and importance values for the leading dominants in the three areas at Burgner Acres. Also included is the importance values for these species from the 1964 survey and the amount of change from the present survey.

Species	Number of Trees per Acre by Diameter Class 4-6	7-12	13-24	25 +	Total	Av. Diam.	Rel. Freq.	Rel. Den.	Rel. Dom.	I.V. 1982	I.V 1964	I.V. Change
AREA A												
WA	25.3	7.1	1.2	--	33.6	6.5	15.1	15.9	10.0	41.0	13.2	+27.8
H	56.4	19.1	--	.4	75.9	6.2	20.4	35.8	22.1	78.3	51.2	+27.1
E	31.5	11.2	.8	--	43.5	6.3	19.2	20.6	12.2	52.0	32.1	+19.9
BW	4.6	8.3	7.5	1.2	21.6	11.7	12.2	10.2	23.2	45.7	46.3	- .6
SH	1.7	--	.8	.8	3.3	14.6	4.7	1.6	6.4	12.7	16.3	- 3.6
WO	1.2	--	1.2	--	2.4	14.3	2.3	1.2	4.5	8.0	12.4	- 4.4
MH	.4	--	--	--	.4	6.9	.6	.2	.1	.9	--	+ .9
RH	2.1	--	--	--	2.1	4.7	2.3	1.0	.3	3.6	28.8	-25.2
DE	3.7	4.2	--	--	7.9	7.3	7.6	3.7	2.9	14.2	32.9	-18.7
BH	--	--	--	--	--	--	--	--	--	--	--	--
BC	5.4	2.5	--	--	7.9	6.2	5.8	3.7	2.0	11.5	11.1	+ .4
SO	2.5	.8	--	--	3.3	6.4	2.3	1.6	1.0	4.9	1.2	+ 3.7
Others	3.7	3.7	1.2	1.2	9.8	17.8	7.5	4.5	15.2	27.2	54.5	-27.3
	138.5	56.9	12.7	3.6	211.7	--	100.0	100.0	100.0	300.0	300.0	
AREA B												
WA	14.9	12.6	5.6	2.3	35.4	10.0	15.4	19.3	25.8	60.5	49.4	+11.1
H	19.5	11.0	1.5	.5	32.5	7.1	14.2	17.8	10.4	42.4	25.0	+17.4
E	31.8	11.8	--	--	43.6	6.2	16.6	23.8	9.1	49.5	40.2	+ 9.3
BW	--	1.5	4.4	.8	6.7	17.5	6.9	3.6	11.5	22.0	24.0	- 2.0
SH	5.9	10.0	7.2	--	23.1	10.7	12.1	12.6	16.2	40.9	40.9	--
WO	.3	.3	.5	1.8	2.9	24.2	3.3	1.5	9.5	14.3	15.1	- .8
MH	.3	2.0	1.5	--	3.8	11.2	4.2	2.1	2.7	9.0	9.2	- .2
RH	10.8	.8	--	--	11.6	5.1	7.8	6.3	1.6	15.7	26.0	-10.3
DE	5.4	1.5	--	--	6.9	6.1	6.9	3.8	1.5	12.2	26.3	-14.1
BH	2.8	2.3	.8	--	5.9	8.6	3.3	3.2	2.9	9.4	6.8	+ 2.6
BC	1.3	.8	--	--	2.1	6.5	2.1	1.1	.5	3.7	2.6	+ 1.1
SO	.8	.8	.8	--	2.4	11.2	1.2	1.3	1.8	4.3	3.9	+ .4
Others	3.1	2.3	.8	.5	6.7	12.1	6.0	3.6	6.5	16.1	30.6	-14.5
	96.9	57.7	23.1	5.9	183.6	--	100.0	100.0	100.0	300.0	300.0	

Table 3. continued

Species	Number of Trees per Acre by Diameter Class 4-6	7-12	13-24	25+	Total	Av. Diam.	Rel. Freq.	Rel. Den.	Rel. Dom.	I.V. 1982	I.V 1964	I.V. Change
AREA C												
WA	62.3	19.6	2.2	.4	84.5	6.4	20.2	43.0	20.7	83.9	55.1	+28.8
H	15.7	6.5	1.3	--	23.5	7.0	11.2	12.0	7.0	30.2	16.5	+13.7
E	15.3	4.4	--	--	19.7	5.9	12.2	10.0	3.6	25.8	29.5	− 3.7
BW	.4	.4	5.7	.4	6.9	17.2	6.9	3.6	11.0	21.5	20.8	+ .7
SH	1.3	7.0	3.5	--	11.8	11.1	8.0	6.0	7.8	21.8	28.0	− 6.2
WO	1.3	--	1.3	4.4	7.0	22.9	6.9	3.6	20.8	31.3	25.9	+ 5.4
MH	.4	2.6	9.6	--	12.6	15.7	9.6	6.4	16.4	32.4	31.8	+ .6
RH	5.2	.9	--	--	6.1	5.5	5.9	3.1	.9	9.9	21.9	−12.0
DE	1.7	--	--	--	1.7	5.1	1.6	.9	.2	2.7	22.8	−20.1
BH	.9	2.2	2.6	--	5.7	12.4	6.4	2.9	5.0	14.3	13.6	+ .7
BC	1.7	--	--	--	1.7	4.8	1.1	.9	.2	2.2	.9	+ 1.3
SO	--	--	--	--	--	--	--	--	--	--	--	--
Others	8.8	4.4	2.2	--	15.4	9.4	10.0	7.6	6.4	24.0	33.2	− 9.2
	115.0	48.0	28.4	5.2	196.6	--	100.0	100.0	100.0	300.0	300.0	

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FIRST REPORT OF *Ricciocarpus natans* (L.) CORDA (MARCHANTIALES: RICCIACEAE) FROM A STRIP MINE IMPOUNDMENT

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ABSTRACT

The first record of *Ricciocarpus natans* (L.) Corda from a coal strip mine impoundment is reported.

INTRODUCTION

The Purple-fringed Riccia, *Ricciocarpus natans* (L.) Corda (Marchantiales: Ricciaceae), is an amphibious hepatophyte occasionally pleustonic in eutrophic ponds and backwaters (Hutchinson 1975). Although this species is distributed throughout the United States (Underwood 1884), to the best of my knowledge, it has never been reported from a coal strip mine impoundment. On 3 March 1983, *R. natans*, in association with *Lemna minor* L., was collected from a spoil-depression pond (type A strip mine impoundment of Arata (1959)) located on the old Peabody Coal Company's Little John Mine No. 5 in Knox County (T12N-R3E-Sec. 35), Illinois.

The most important factor influencing the distribution of aquatic plants is water chemistry (Hutchinson 1975, Moyle 1945). Water quality in this particular pond (Table 1) was characteristic of other strip mine waters in Illinois (cf. Gibb and Evans 1978, Konik 1980, Lewis and Peters 1954). As distribution records rarely include ancillary chemical data, little can be discerned about the environmental tolerances of *R. natans*. However, observed conductively, TDS, and SO_4 (Table 1) were the highest levels reported for any locality supporting this organism.

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Table 1. Major water chemistry parameters for spoil-depression pond, Little John Mine No. 5, Knox County, Illinois, October 1982.*

pH	6.1
Conductivity	1,000.0 υmhos cm^{-1}
TDS	1,564.0 ppm
Alkalinity	176.0 ppm $CaCO_3$
Acidity	128.0 ppm $CaCO_3$
SO_4	1,056.0 ppm
Ca	115.4 ppm
K	8.0 ppm
Mg	148.0 ppm
Na	29.2 ppm
P	0.4 ppm
Si	1.2 ppm

*All other elemental concentrations 0.25 ppm.

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LIVERWORTS AND HORNWORTS OF GARDEN OF THE GODS, SHAWNEE NATIONAL FOREST, SALINE COUNTY, ILLINOIS

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ABSTRACT

Exposed rock outcrops with hill prairie vegetation, moist vertical sandstone canyon walls, mesic woodlands and shaded stream banks within Garden of the Gods provide microhabitats for 38 liverwort and two hornwort taxa. This flora comprises species common to the Interior Highlands, including well established populations of *Nowellia curvifolia* (Dicks.) Mitt. and *Trichocolea tomentella* (Ehrh.) Dum. Thirty-two taxa are reported for the first time from Saline County, and *Lophozia bicrenata* (Schmid. ex Hoffm.) Dum., an often abundant species in disturbed lands of eastern North America, is reported for the first time from Illinois. A previous report of *Jungermannia hyalina* Lyell from this region could not be verified.

INTRODUCTION

The exposed rock outcrops for which Garden of the Gods, a widely visited scenic area of the Shawnee National Forest, is famous are comprised of Pounds Sandstone of Pennsylvanian strata. Strangely contorted, circular rock formations with various shapes and patterns result from differential weathering of the uniquely intermixed resistant iron oxide bands and sandstone layers of this deposition. In addition to a bold, often rugged relief, the natural beauty of this small region in the unglaciated region of the Shawnee Hills is enhanced by moist ravines and a gradient of mesic to xeric woodlands. Such topographic and macroflora variability

provide microenvironments that support an equally well established hepatic/anthocerote flora that is both abundant and floristically diverse.

Located in the southeast corner of Saline County, Garden of the Gods has a continental climate typical of Southern Illinois. Low pressure fronts which bring about frequent, often rapid changes in humidity, temperature, solar radiation and wind direction are characteristic of the region, and annual precipitation averages 41″. As in other canyons of the area this type of regime supports the establishment of a mixture of southern Appalachian, temperate and boreal species of both vascular and nonvascular plants.

Previous reports of liverwort or hornwort taxa from Garden of the Gods and Saline County are few. Seven liverwort species were recorded by Hague and Drexler (1938) from Stillhouse Hollow in Saline County, including the relatively rare *Scapania undulata* (L.) Dum., a species likewise collected in this study. Skorepa (1968) listed six common Illinois species from Garden of the Gods in his general treatment of liverworts of Southern Illinois.

This investigation was then undertaken to examine the diversity of liverworts and hornworts in this floristically rich yet relatively unexplored area. Specimens were collected on numerous sampling trips over the course of three years. Previous collections made by Redfearn, Skorepa, Zehr and Skorepa and Sharp were examined and annotated where appropriate. All collections are deposited in the herbarium of Southern Illinois University [SIU].

RESULTS AND DISCUSSION

Thirty-eight liverwort and two hornwort taxa were found in the Garden of the Gods. Of these, one species *Lophozia bicrenata* (Schmid. ex Hoffm.) Dum. is new to the Illinois flora. In fact, this is the first report of this genus in the State. Several essentially "northern" species, such as *Nowellia curvifolia* (Dicks.) Mitt. and *Trichocolea tomentella* (Ehrh.) Dum., occur abundantly on decorticate logs and shaded creek banks, respectively. Exposed sandstone outcrops provide suitable habitats for typically Appalachian species like *Frullania tamarisci* (L.) Dum. subsp. *asagrayana* (Mont.) Hatt., while moist, vertical sandstone canyon walls support a mix of taxa common to southern Illinois, including circumboreal to montane elements like *Bazzania tricrenata* (Wahlenb.) Lindb. and *Marsupella sphacelata* (Gieske) Dum., low elevation Appalachian species like *Jungermannia fossombronioides* Aust., *Lophocolea bidentata* (L.) Dum. and *Leucolejeunea clypeata* (Schwein.) Evans, as well as ubiquitous forms like *Jamesoniella autumnalis* (DC.) Steph., *Pellia epiphylla* (L.) Corda and *Plagiochila porelloides* (Torrey ex Nees) Lindb. Markedly southern affinities are further suggested within the morphotypes of *Lophocolea heterophylla* (Schrad.) Dum. and *Cephalozia catenulata* (Hüb.) Lindb. In the former, one well developed population produces abundant gemmae in chain-like filaments, a trait which Schuster (1980) has segregated in *L. heterophylla* subsp. *cladogyna* Schust., a taxon "known only from the southeastern Coastal Plain" (Schuster, 1980). Unlike members of this subspecies, however, the Garden of the Gods population does not possess abbreviated female branches, and thus appears intermediate between *L. heterophylla* subsp. *heterophylla* and *L. heterophylla* subsp. *cladogyna*. Intermediacy likewise exists in *C. catenulata* populations, which are vegetatively of typical form but reproductively possess the long, leafy gynoecial axes of the southern Appalachian genotype, *C. catenulata*

fo. *grandiretis*. Examination of specimens upon which earlier reports were based showed that *Plectocolea hyalina* (Lyell) Mitt. (= *Jungermannia hyalina* Lyell) reported by Skorepa (1968) was a misidentified *Jungermannia gracillima* Sm.

Of the 40 taxa included in the checklist that follows, 32 indicated by *, are being reported for the first time from Saline County and one, designated by **, is being reported for the first time from Illinois. The nomenclature used in the list is that of the most recent checklist of American hepatics and anthocerotes (Stotler & Crandall-Stotler, 1977).

Checklist of Taxa in Garden of the Gods, Shawnee National Forest, Arranged Alphabetically

Division Anthocerotophyta (hornworts)

* 1. *Anthoceros punctatus* L. — Occasional on moist soil in lowland areas or along creek banks, localized populations mixed with *Phaeoceros laevis; Renzaglia 160, 416.*

2. *Phaeoceros laevis* (L.) Prosk. — Common on soil in moist lowland and creek banks, intermixed with *Anthoceros punctatus; Renzaglia 161, 414.*

Division Hepatophyta (liverworts)

* 3. *Asterella tenella* (L.) Beauv. — Occasional on soil along trail or mixed with hornworts along banks of creek; *Renzaglia 162, 170; Crandall-Stotler 2001.*

* 4. *Bazzania tricrenata* (Wahlenb.) Lindb. — Rare on vertical shaded sandstone, mixed with *Odontoschisma prostratum* and *Scapania nemorea; Skorepa 4835.*

* 5. *Calypogeja muelleriana* (Schiffn.) K. Müll. subsp. *muelleriana* — Abundant in a variety of habitats such as soil along trails and shaded sandstone cliffs; *Renzaglia 407 p.p.; Redfearn 20432; Skorepa s.n.*

* 6. *Cephalozia catenulata* (Hüb.) Lindb. — Common on moist decorticate logs in lowland woods. These populations are intermediate between the common variety and the southern Appalachian form *C. catenulata* fo. *grandiretis*; i.e., the vegetative plants are as in typical *C. catenulata* but the female branches are elongate as in *C. catenulata* fo. *grandiretis; Renzaglia 183, 205.*

* 7. *Cephaloziella divaricata* (Sm.) Schiffn. var. *divaricata* — Occasional on exposed soil along upland path, intermixed with *Lophozia bicrenata; Renzaglia 206, 417 p.p.*

* 8. *Cololejeunea biddlecomiae* (Aust.) Evans — Common on rocks and decaying logs in creek beds; *Renzaglia 180, 185 p.p., 191, 195, 406.*

* 9. *Conocephalum conicum* (L.) Lindb. — Occasional on soil along creek beds in ravine; *Renzaglia 193.*

*10. *Diplophyllum apiculatum* (Evans) Steph. — Abundant along vertical sandstone cliffs in lowland areas., intermixed with *Odontoschisma prostratum, Scapania nemorea* and *Jubula pennsylvanica; Renzaglia 175, 413; Redfearn 20453; Skorepa s.n.*

*11. *Fossombronia* (Raddi) *c.f. foveolata* — Common on exposed soil along trails in upland areas, sometimes intermixed with *Calypogeja muelleriana* or *Asterella tenella; Crandall-Stotler 2002, 2003.*

*12. *Frullania eboracensis* Gott. — Abundant on tree bark and decaying logs; *Renzaglia 171, 172, 185 p.p., 186, 403, 410.*

*13. *Frullania inflata* Gott. — Common on *Juniperus* in xeric upland woods; *Renzaglia 190, 402, 418; Crandall-Stotler 2003.*

*14. *Frullania riparia* Hampe ex Lehm. — Rare, only one population found, growing on base of *Fraxinus; Skorepa* & *Sharp 3762.*

15. *Frullania tamarisci* (L.) Dum. subsp. *asagrayana* (Mont.) Hatt. — Occasional on vertical sandstone in dry upland woods and on exposed rock outcrops; *Renzaglia 203; Skorepa* & *Sharp 3776.*

*16. *Jamesoniella autumnalis* (DC.) Steph. — Abundant on moist rocks and decaying logs; *Renzaglia 201, 202.*

17. *Jubula pennsylvanica* (Steph.) Evans — Common on moist vertical sandstone cliffs and rocks in creeks; *Renzaglia 177, 184, 196, 400, 407; Skorepa 4032.*

*18. *Jungermannia crenuliformis* Aust. — Common on rocks in stream and on moist sandstone bluffs; *Renzaglia 400, 405; Crandall-Stotler 2005; Skorepa 4033.*

*19. *Jungermannia fossombronioides* Aust. — Occasional on moist sandstone bluff and on wet rocks along creeks; *Renzaglia 189, 415.*

*20. *Jungermannia gracillima* Sm. — Occasional on exposed soil along upland trails; *Renzaglia 174; Crandall-Stotler 2006, 2007; Skorepa 4033.*

*21. *Leucolejeunea clypeata* (Schwein.) Evans — Common on vertical sandstone; *Redfearn 20427.*

*22. *Lophocolea bidentata* (L.) Dum. — Locally abundant on rocks in creeks, associated with *Jubula pennsylvanica; Crandall-Stotler 2007; Renzaglia 187.*

23. *Lophocolea heterophylla* (Schrad.) Dum. — Common in a variety of habitats including rocks and decaying logs. One population, represented by *Renzaglia 182*, shows characters that are intermediate between *L. heterophylla* subsp. *heterophylla* and the southern Coastal Plains genotype, *L. heterophylla* subsp. *cladogyna*, in being paroicous and possessing typical, terminal gynoecia of the former but numerous single-celled gemmae of the latter. This combination of characters further illustrates the north-south mixture of the flora; *Renzaglia 181, 182, 185 p.p., 191 p.p.; Crandall-Stotler 2008; Skorepa* & *Sharp 3774.*

*24. *Lophocolea minor* Nees — Rare, one population encountered on moist, shaded vertical sandstone in canyon. This gemmiparous species differs from the gemma-producing population of *L. heterophylla* in being dioicous and much smaller, with the gemmae produced in globose masses along the consequently eroded leaf margins; *Crandall-Stotler 2010.*

**25. *Lophozia bicrenata* (Schmid. ex Hoffm.) Dum. — Rare, one large population on exposed soil along trail in the upland area; although this species has "weedy" propensities, it has not been previously reported in Illinois nor has it been collected at similar sites in Southern Illinois; *Renzaglia 172, 412, 417.*

26. *Marsupella sphacelata* (Gieske) Dum. — Occasional on vertical, shaded sandstone; *Sharp* & *Skorepa 3767* as *M. sullivantii* (De Not.) Evans (= *M. sphacelata*).

*27. *Metzgeria conjugata* Lindb. — Occasional, large populations in seepage areas of vertical sandstone cliffs; *Renzaglia 198.*
*28. *Metzgeria furcata* (L.) Dum. — Rare in moist, shaded areas on vertical sandstone; *Renzaglia 171, 196 p.p.*
*29. *Nowellia curvifolia* (Dicks.) Mitt. — Occasional, large populations on decorticate logs in shaded lowland forest; *Renzaglia 178.*
*30. *Odontoschisma prostratum* (Sw.) Trev. — Abundant on vertical sandstone in lowland forests; *Renzaglia 176; Redfearn 20425; Skorepa 4835 p.p.*
*31. *Pellia epiphylla* (L.) Corda — Common on moist sandstone and soil in ravine areas; *Renzaglia 194, 197, 407 p.p.; Skorepa s.n.*
*32. *Plagiochila porelloides* (Torrey ex Nees) Lindenb. — Abundant on rocks in creek beds and on vertical sandstone; *Renzaglia 173, 196 p.p., 407 p.p., 408 p.p.; Redfearn 20424.*
33. *Porella pinnata* L. — Occasional on rocks along creeks and seepage areas of sandstone outcrops, associated with *Frullania eboracensis* and *Cololejeunea biddlecomiae; Renzaglia 179, 204.*
*34. *Porella platyphylloidea* (Schwein.) Lindb. — Common on decorticate logs and bark of trees, associated with *Cololejeunea biddlecomiae, Lophocolea heterophylla* and *Frullania eboracensis; Renzaglia 185, 401, 402, 404.*
*35. *Radula obconica* Sull. — Occasional on rocks in creek beds; *Renzaglia 173 p.p., 205; Redfearn 20427 p.p.; Skorepa 4034.*
*36. *Riccia dictyospora* M.A. Howe — Rare in small pools of water on bluff tops; *Renzaglia 200.*
*37. *Riccia hirta* (Aust.) Underw. — Rare on bluff tops; *Renzaglia 188.*
38. *Scapania nemorea* (L.) Grolle — Common in numerous habitats including soil and sandstone; *Renzaglia 409; Crandall-Stotler 2015; Redfearn 20473; Skorepa 11018, 40835 p.p.; Zehr s.n.*
39. *Scapania undulata* (L.) Dum. — Abundant in localized areas on rocks in creek, periodically submerged; *Renzaglia 199; Zehr s.n.*
*40. *Trichocolea tomentella* (Ehrh.) Dum. — Abundant on soil along creek bed, localized populations; *Renzaglia 192.*

CONCLUSIONS

The liverwort/hornwort flora of Garden of the Gods, Shawnee National Forest, Saline County, Illinois, is a rich blend of phytogeographically diverse elements of boreal, Appalachian, Costal Plain and eastern deciduous forest affinities. As in other natural sandstone gorges of the Ozark Hills formation, a variable, unglaciated terrain provides the microniches necessary for the maintenance of floristic heterogeneity. With a composition of 40 taxa, 32 newly reported for Saline County, this area is floristically more or less comparable to Ferne Clyffe State Park, Johnson County (Zehr & Stotler, 1980 [1981]), Lusk Creek Canyon Nature Preserve, Pope County (Crandall-Stotler & Stotler, 1978 [1979]), and Little Grand Canyon, Jackson County (Stotler, 1976), and is more polymorphic than Panther's Den, Union County (West & Stotler, 1977). Of most interest is the discovery of *Lophozia bicrenata*, a species not encountered in any of these other gorges and, in fact, not previously reported for the state even though its occurrence in our geographic region is not unexpected.

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NOTES ON THE DISTRIBUTION OF SOME VASCULAR PLANTS OF NORTHERN ILLINOIS

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ABSTRACT

Collection data and notes concerning geographic distribution are provided for 28 vascular plant species of Northern Illinois that are vouchered in the herbarium at Northern Illinois University (DEK). One species, *Solanum villosum*, is reported from Illinois for the first time.

NOTES ON THE DISTRIBUTION OF SOME NORTHERN ILLINOIS VASCULAR PLANTS

Beginning with the growing season of 1971 and continuing to the present my students and I have actively engaged in adding to the herbarium holdings at DEK. The emphasis has been to acquire a complete as possible assemblage of the local flora, primarily for teaching purposes. As a result of this activity several taxa have been added to the known vascular flora of our immediate area, DeKalb County, as well as to the flora of the region and the state. It is my purpose to report here the accumulated records on these rare or noteworthy vascular plants.

Our efforts to keep abreast of an understanding and recognition of our flora have been greatly aided by the distribution information contained in the various editions of *Plants of the Chicago Region*, by Floyd Swink of the Morton Arboretum. The "3rd" and latest edition, by Swink and Wilhelm (1979), described as the "Revised and Expanded Edition," has been particularly useful because it goes beyond the checklist format to include keys and many taxonomic notes. We are fortunate that Swink and Wilhelm include DeKalb County in their circumscription of the "Chicago region."

We have also found useful the "Checklist of the Vascular Flora of Illinois" with its two addenda, by Robert H. Mohlenbrock (1976A, B, & 1977). At the present time this checklist is available only in mimeograph copy.

Taxa reported below are arranged alphabetically by genera followed by data

on location, habitat, collector, collector's number, and date. For most taxa I have provided a brief discussion pertaining to their occurrence and taxonomy. Unless otherwise stated the species are additions to the known flora of the counties given. One species, *Solanum villosum*, is reported as new to Illinois. Voucher specimens are on deposit at DEK. When available duplicates have been or will be deposited at MOR and ISM. Taxa presumed not native to Illinois bear an asterisk preceding their name.

**Acer pseudoplatanus* L.

DeKalb Co. Adventive in fence-row along Fairview Dr., DeKalb city; soil fine-textured. *Sörensen 7273*, 16 Oct 1972. This species has not previously been reported as adventive or escaping cultivation in Illinois. Fernald (1950), who spells the specific epithet, "Psuedo-Platanus," lists the species as freely escaping but does not provide a geographic range in NEUS. Rehder (1951) indicates the species is native in Europe and Western Asia, and gives its English name as Sycamore Maple. I have watched this population over the years and it has decidedly increased with many different sizes and ages of plants present indicating repeated "seeding-in"; however, I doubt it poses a threat as a nuisance species. The parent is a large specimen (8 m, DBH 0.8 m) planted many years ago in nearby Fairview Cemetery as an ornamental and shade tree.

Androsace occidentalis Pursh

DeKalb Co. Ledges created by flagstone slope along S bank of Watson Creek on the campus of Northern Illinois University; scattered in open patches of accumulated fine-textured soil among flagstones. *Sörensen et al. 8118B*, 16 Apr 1981. The habitat where this species was collected dates from its construction in 1972. Since then the site has become thoroughly colonized by adventives and occasionally by such interesting natives as this one.

Arenaria stricta Michx.

DeKalb Co. Thin soil on limestone ledges of an active quarry, 1 km S of Fairdale, 7 km W of Kirkland. *Sörensen & Muller 7650*, 23 Jul 1977. At this site also occur such notable species as *Isanthus brachiatus* and *Aster oblongifolius*. The former is listed below as new for Dekalb Co.

Asclepias lanuginosa Nutt

DeKalb Co. On the property of Mr. Donald Faivre, 10.4 km SE of Dekalb city along Somonauk Rd; S-facing slope of a gravelly moraine or kame. *Sörensen 7028*, 9 Jun 1971; & *7553*, 23 Aug 1976. Although not new to the flora this population is of special interest because it flowers and fruits annually as I have observed on several visits to the site. Dr. Robert Betz, who has studied the genus *Asclepias* and is well-known for his enthusiasm concerning the prairie milkweeds in particular, has stated that *A. lanuginosa* is known to produce fruit only rarely and he attributes this fact to the possible extirpation of the pollinators. It is worthwhile, therefore, to observe that, at least here, the appropriate pollinators must still be present and the well-being of the population of this Illinois endangered species (Bowles, 1981) for the present seems assured.

**Asclepias speciosa* Torr.

DeKalb Co. 1.7 km W of DeKalb city along the CNWRR tracks; degraded prairie in RR right-of-way. *Sörensen 8396*, 17 Jul 1983. This species is a rare adventive introduced from the Great Plains arriving perhaps as a seed in the bedding straw of cattle cars at the time when cattle were still hauled by rail. Swink & Wilhelm (1979) report its occurrence in two other locations within the Chicago region. At the DeKalb Co site this species has hybridized freely with our local *A. syriaca*. Obvious individuals representing the F_1 generation can be seen as well as several that are likely the result of backcrossing to the parents. My judgement of intermediacy is based largely upon comparisons of flower size.

Aster cordifolius L.

DeKalb Co. Huber Park in DeKalb city, N end of park in wooded area near the CNWRR tracks, only a single plant seen. *Koehring 64*, 10 Oct 1978. The habitat for this species seems unusual inasmuch as Swink & Wilhelm (1979) describe it as a species of rich Sugar Maple forests and indicate its principal occurrence in the Chicago region is near Lake Michigan, especially in Berrien Co, Michigan.

Astragalus canadensis L.

DeKalb Co. Along W County Line Rd, 2.4 km N of Ill Rt 38, on E side of right-of-way; degraded prairie remnant. *Sörensen* & *Wade 7577*, 17 Sep 1976. Subsequent visits to this location have resulted in finding two additional plants. In recent years the DeKalb Co government has greatly reduced the amount of roadside mowing that was previously done which may account for the well-being of this population. Plants here have been observed to set fruit vigorously.

Carex garberi Fern.

Cook Co. Far S side of the City of Chicago, about 96th St in an open, intermittent, shallow wetland between the Norfolk & Western RR right-of-way and the residential area along Vanvlissingen Ave; moist to dry areas of small knoll forming an island in the wetland area; several plants seen. *Sörensen 8232*, 4 Jun 1982. Although not new to Cook Co this recent discovery of a viable population of this species is worth noting inasmuch as it is considered an Illinois endangered species (Bowles, 1981).

Carya illinoensis (Wang.) K. Koch

Ogle Co. Wooded terrace of the Rock R, about 10 km S of Oregon, on E side of river, E 1/2 of Sec 31, R 10 E, T 21 N, on the property of Mr. Albert Dahlberg. *Sörensen* & *Voth 8339*, 14 Oct 1982. This massive specimen (c 20 m, DBH 0.6 m) might have been overlooked had it not been for the fortuitous discovery of a limb that had been blown down in a storm. Enough leaves remained on the fallen branch for an identification and a voucher. There is always the likelihood that this specimen has been planted, but its great size argues against that possibility. The habitat and occurrence as described by Mohlenbrock (1973) fit the site where this one was growing.

Carya tomentosa Nutt.

DeKalb Co. Chief Shabbona County Forest Preserve, 2 km SE of Shabbona, upland forest of *Quercus alba*, *Q. macrocarpa*, and *Carya ovata*. *Kline* & *Sörensen*

103, 23 Jul 1980. Despite many previous visits to this site the Mockernut has been completely overlooked. In 1982 I made a reconnaisance of the forest and I now have concluded that Mockernut is, in fact, the prevailing hickory species present here. Moreover, there is abundant reproduction taking place as is evident from the numerous seedlings and young saplings present especially in the north and west part of the preserve. DEK also has a specimen from LaSalle Co (*Kukowski s.n.*, 13 May 1962), but specific location data are not given. Each represents a northward range extension beyond that shown by Mohlenbrock (1973).

Cornus alternifolia L.f.

DeKalb Co. Russell Forest Preserve, just S of Ill Rt 72 between Genoa and Kirkland; rich upland woods with Sugar Maple, Basswood, and Bitternut Hickory among the most abundant canopy trees. *Muller 1487A*, Jul 1975. That this species should eventually turn up in DeKalb Co seems expected inasmuch as it is well-known from surrounding geographic areas and ample habitat for it can be found here.

Eleocharis obtusa (Willd.) Schultes

DeKalb Co. Kishwaukee Community College Campus, Malta; exposed shores of artificial pond, fine-textured substrate. *Sörensen 7587*, 28 Sep 1976. Since the collection reported here was made, the species has been sighted in a similar habitat, i.e., along the shores of an artificial pond, on the west campus of Northern Illinois University, and later also along the banks of Watson Cr that crosses the campus. Along the pond shores I have watched the populations "bloom" in the years just after the creation of the habitat, after which a marked decline coincided with the gradual colonization of the shores by perennial sedges and rushes. It is now not at all abundant at any of these sites.

**Erodium cicutarium* (L.) L'Her.

DeKalb Co. Campus of Northern Illinois University, disturbed open soil at SW corner of Davis Hall along Normal Rd. *Friberg s.n.*, 15 Oct 1981.

**Eriochloa villosa* (Thunb.) Kunth

DeKalb Co. About 20 km N of DeKalb city near jct with Annie Glidden Rd and Milwaukee Road RR tracks; gravelly ballast at edge of degraded prairie remnant. *Sörensen 7679*, 6 Oct 1977. At a later date, late 1978, this species was observed as a rank weed in a cornfield about 4 km S of the above site. The statement by Swink & Wilhelm (1979) that this species "has the potential of becoming weedy," seems prophetic. It gives every sign of having the phenology and weediness of Fall panicum (*P. capillare*). Pohl (1959) reported this species as a potential weed in Iowa more than two decades ago. I am indebted to him for verification of the identity of our material.

**Holosteum umbellatum* L.

DeKalb Co. Campus of Northern Illinois University, about stonework at N end of Swen Parson Library (now the Law School); with *Lamium amplexicaule* and *Capsella bursa-pastoris*. *Sörensen 7623*, 11 Apr 1977.

Isanthus brachiatus (L.) BSP.

DeKalb Co. Thin soil on limestone ledges of an active quarry, 1 km S of Fairdale, 7 km W of Kirkland. *Sörensen & Muller 7651*, 23 Jul 1977.

Juncus bufonius L.

DeKalb Co. Exposed mud along shores of small pond on the campus of Kishwaukee Community College, Malta. *Sörensen 7610*, 9 Oct 1976. The population of this species has behaved much the same as that of *Eleocharis obtusa* (see above) with which it co-occurs. When first found it was quite abundant having reached a peak in numbers of plants. Since then the numbers have declined such that during the 1982 season it was not observed at all.

Kane Co. Moist sandy soil in the SE quadrant of the intersection formed by I-90 (Northwest Tollway) and Ill Rt 47. *Trager 51*, 5 Aug 1972.

Juncus dudleyi Wieg.

DeKalb Co. In moist gravelly and cindery soil just N of Pleasant St along a local RR spur (now abandoned) in the E part of DeKalb city. *Trager 27*, 13 Jul 1972. A second specimen at DEK (*Sörensen 7611*, 9 Oct 1976) was collected at the Kishwaukee Community College pond (see *J. bufonius*, above).

Juncus gerardi Loisel.

Cook Co. South of 103rd St along Stony Island Avenue extension (not a developed road) in the far south side of Chicago; depression of a poorly-drained and seasonally-inundated field where the vegetation has developed upon filled land. *Sörensen 8278*, 8 Jul 1982. As reported by Swink & Wilhelm (1979) this rare species of the Chicago region flora was collected by Glassman at 92nd and Stony Island Ave in 1956. Inasmuch as the earlier station is no doubt now destroyed I think it is worthwhile to report this newly-discovered site that lies 2.8-3.0 km S of the original Cook Co locality. There is, however, not a great deal of hope that the Cook Co populations of this species will remain long, since the site reported here is adjacent to active landfill areas and could be covered over at any time.

**Leonurus marrubiastrum* L.

DeKalb Co. Among sedges (*Carex stricta*) in a meadow developed on a terrace of the Kishwaukee River just W of Huber Park in the south sector of DeKalb city. *Sörensen 7586*, 27 Sep 1976; and just S of the CNWRR tracks and W of Annie Glidden Rd in SW DeKalb city; fine-textured fill with *Daucus carota*, *Acer negundo*, and *Morus alba*. *Sörensen 8333*, 18 Sep 1982. This infrequent and introduced weed seems now to have naturalized in our local flora.

Orobanche uniflora L.

DeKalb Co. Disturbed upland forest, SE corner of the Northern Illinois University campus, "the campus woods," near Ill Rt 38, in thickety undergrowth of *Ribes americanum*, *Cornus racemosa*, and *Lonicera tartarica*. *Sörensen 8021*, 6 Jun 1980.

Potamogeton natans L.

Cook Co. Clay-bottomed "borrow pit," 0.8-1.4 km S of US Rt 30 on W side of

I-57 in town of Mattheson, in shallow water among clumps of *Scirpus* and *Typha*. *Sörensen 7604*, 2 Oct 1976.

Sambucus pubens Michx.

DeKalb Co. About 2 km NW of Kingston along the Kishwaukee R; E-facing springy seepage slope, with *Symplocarpus foetidus*, *Fraxinus nigra*, and *Carpinus caroliniana*. *Sörensen* & *Matekaitis 7792*, 8 May 1980.

Scirpus paludosus Nels.

Cook Co. At approximately 110th St near Stony Island Ave extension (not a developed rd) in the far south side of Chicago; muddy banks of a ditch or drainway leading from the Norfolk & Western RR loading yard to the NE corner of Lake Calumet, through an area built up with cindery fill. *Sörensen 8302*, 10 Aug 1982. Swink & Wilhelm (1979) report this species from elsewhere in Cook Co. The taxon is listed as an Illinois endangered species (Bowles, 1981). The behavior of this species at the station reported here and as intimated by its similar ecology noted by Swink & Wilhelm suggest that the populations in Cook Co are of recent introduction from the western mountain states where it is abundant. Its occurrence in the Chicago region is quite likely a result of recently increased habitat based upon industrialization and associated wastes. In my opinion one can expect to see an increase in this species paralleling that of such tollway followers as *Typha angustifolia*.

**Solanum villosum* Mill.

DeKalb Co. Newly exposed cindery and gravelly soil of RR right-of-way at intersection of CNWRR and Nelson Rd, 3.2 km W of DeKalb city. *Sörensen 8335*, 25 Sep 1982. The occurrence of this Eurasian weed in Illinois is reported here for the first time (Mohlenbrock, 1976A, B, & 1977). Fernald (1950) gives its adventive range in NEUS as "Mass. south." Its habit is very similar to that of the common *S. americanum* but it is markedly different from that species by its dense, somewhat glutinous, hairy vestiture.

**Spergularia marina* (L.) Griseb.

DeKalb Co. Campus of Northern Illinois University, in fine-textured soil of parkway where grasses have been worn away by foot traffic, NW corner of Stevenson Residence Halls. *Sörensen 8305*, 11 Aug 1982. Swink & Eilhelm (1979) argue that populations of *Spergularia* in the Chicago region tend to share the characters used to separate *S. marina* and *media*. Based upon the habitat where these occur I would expect *S. media*, the introduced species (Fernald, 1950), to be the more prevalent. However, I have chosen to recognize *S. marina* as the correct name to apply to the present collection since the characters possessed seem quite clear: wingless seeds, short pedicels, narrow leaves in opposite pairs (not fascicled). Whatever are the merits of the uncertainty alluded to here, one thing seems sure, namely that our local plants are of recent introduction and should be considered naturalized rather than native.

Viola conspersa Reichenb.

DeKalb Co. Adventive in lawns and flower beds around my residence at the corner of Susan Ct & Sharon Dr in the far SW corner of DeKalb city; soil fine-

textured. *Sörensen 8120*, 4 May 1981. This species first appeared in 1975 in the shade beneath a small cultivated specimen of *Tsuga canadensis*. Since then it has spread freely into the Blue Grass lawn and among shrubs and cultivated perennials in flower beds. No doubt it has been introduced by me or has come along with potting soil of a garden plant. In any case it now seems happily established and I have not discouraged it.

Zannichellia palustris L.

DeKalb Co. Bullrun Cr in Kirkland, near passage beneath Ill Rt 72; muddy substrate, water shallow, with *Nasturtium officinale. Pooley 14C*, 29 Sep 1979. While this report of the Horned-pondweed is interesting in itself it is worthwhile to note that the occurrence in DeKalb Co of Water Cress is here first reported; however, no voucher for the latter exists at the present time.

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HEDRURIS SIREDONIS FROM AMBYSTOMA TAYLORI ENDEMIC TO LAGUNA ALCHICHICA PUEBLA, MEXICO

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ABSTRACT

Five of 34 salamanders collected from Laguna Alchichica, Puebla, Mexico were infected with *Hedruris siredonis*. The occurrence of *H. siredonis* in *Ambystoma taylori* constitutes a new host record for this nematode.

Although the nematode *Hedruris siredonis* Baird, 1858, has been reported from caudate amphibians in the contiguous United States and Mexico, its geographic distribution is probably limited to Mexico. Chandler (1919) identified a frequently occurring nematode of *Taricha torosa* of Oregon tentatively as *H. siredonis*. Since Baird's account of *H. siredonis* was based on a single exiguously described female, the identity of Chandler's specimens could only be inferred from circumstantial evidence. Later, Caballero and Hollis (1938) provided a detailed description of *H. siredonis* based on several mature male and female specimens from a salamander identified as *Ambystoma tigrinum*, collected from Lake Xochimilco, Mexico, D.F. Because of inconsistency in older publications in applying the specific names *tigrinum* and *mexicanum* (Freitas and Lent 1941a, b; Smith, 1969) and because both species may occur sympatrically in parts of Mexico, the actual identity of Caballero and Hollis' host cannot be verified.

In a review of the genus *Hedruris*, Freitas and Lent (1941a) proposed *H. chandleri nom. nov.* for *H. siredonis*, Chandler, 1919 *nec* Baird, 1858, in that *H. chandleri* is distinct from *H. siredonis* redescribed by Caballero and Hollis with respect to the relative positions of the excretory pore and nerve ring and the form of the spicules. Specimens reported by Lehmann (1954) from *Taricha granulosa* and *Ambystoma gracile* in Oregon are probably better identified as *H. chandleri*. More recently, Dyer and Brandon (1973) reported *H. siredonis* from *Ambystoma ordinarium* of San Jose Lagunillas, Michoacán, *A.* sp. of Zacapu, Michoacán and *A. subsalsum* of Laguna Alchichica, Puebla.

Of 34 salamanders collected from Laguna Alchichica on 2, March, 1973, 5 were infected with *H. siredonis*. These salamanders were from a neotenic population of *Ambystoma* endemic in Laguna Alchichica that were compared by Brandon *et al.* (1982) with the holotype of *Ambystoma subsalsum* Taylor (1943) and with *A. tigrinum* from several populations in Puebla, Tlaxcala, and Hidalgo. These investigators concluded that the holotype is identifiable as *A. tigrinum* and is specifically different from the Laguna Alchichica neotenes designated as *A. taylori*. This necessitates amendment of the report by Dyer and Brandon (1973, op. cit.) so that the salamander hosts of *H. siredonis* taken at Laguna Alchichica are *A. taylori nec subsalsum*. The occurrence of *H. siredonis* in *A. taylori* constitutes a new host record. Representative specimens are deposited in the USNM Helm. Coll., No. 77156.

The author is grateful to Dr. Ronald A. Brandon, Department of Zoology, Southern Illinois University at Carbondale, for providing specimens of *Ambystoma taylori*.

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A MICROCOMPUTER PROGRAM FOR PERFORMING JOB'S ANALYSIS OF A COMPLEX

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ABSTRACT

A microcomputer program is described which determines the composition of a complex by Job's method and, using a graphics plotter, draws the Job's plot.

INTRODUCTION

In a number of types of situations, it is necessary to determine a break point in a curve that represents some property of a system as a function of concentration. One such situation is that of applying Job's method to the problem of determining the composition of a metal complex (Angelici, 1977; Jones, 1964; Vosburgh and Cooper, 1941). If the equilibrium can be represented as

$$M + nL \rightleftarrows ML_n \qquad (1)$$

where n = 1, 2, 3, . . ., the problem is to determine the number (n) of ligands (L) per metal ion (M). Actually, any electron donor-acceptor interaction that leads to complex formation can be considered as well (Gur'yonova, et al., 1975). In this method, some property of the complex, usually absorbance at some appropriate wavelength, is measured as the concentration of the metal, CM, and the concentration of the ligand, CL, are varied while keeping the total concentration of solution, C, fixed. It can readily be shown that the maximum concentration of the complex, and hence the maximum in the measured property, occurs when the ratio of the concentration of metal to that of ligand in the solution is exactly the same as the ratio present in the complex (Angelici, 1977; Jones, 1964). Thus, in principle, varying the ratio CM/CL in a series of isomolar solutions while measuring the appropriate property of the complex should produce a curve having a maximum (or in some cases a minimum). From the position of this maximum, CM and CL of the solution containing the highest concentration of complex is identified and n is determined. Typically, the curves are sketched from experimental data and the maximum is obtained from the graph. We present here a program in BASIC for

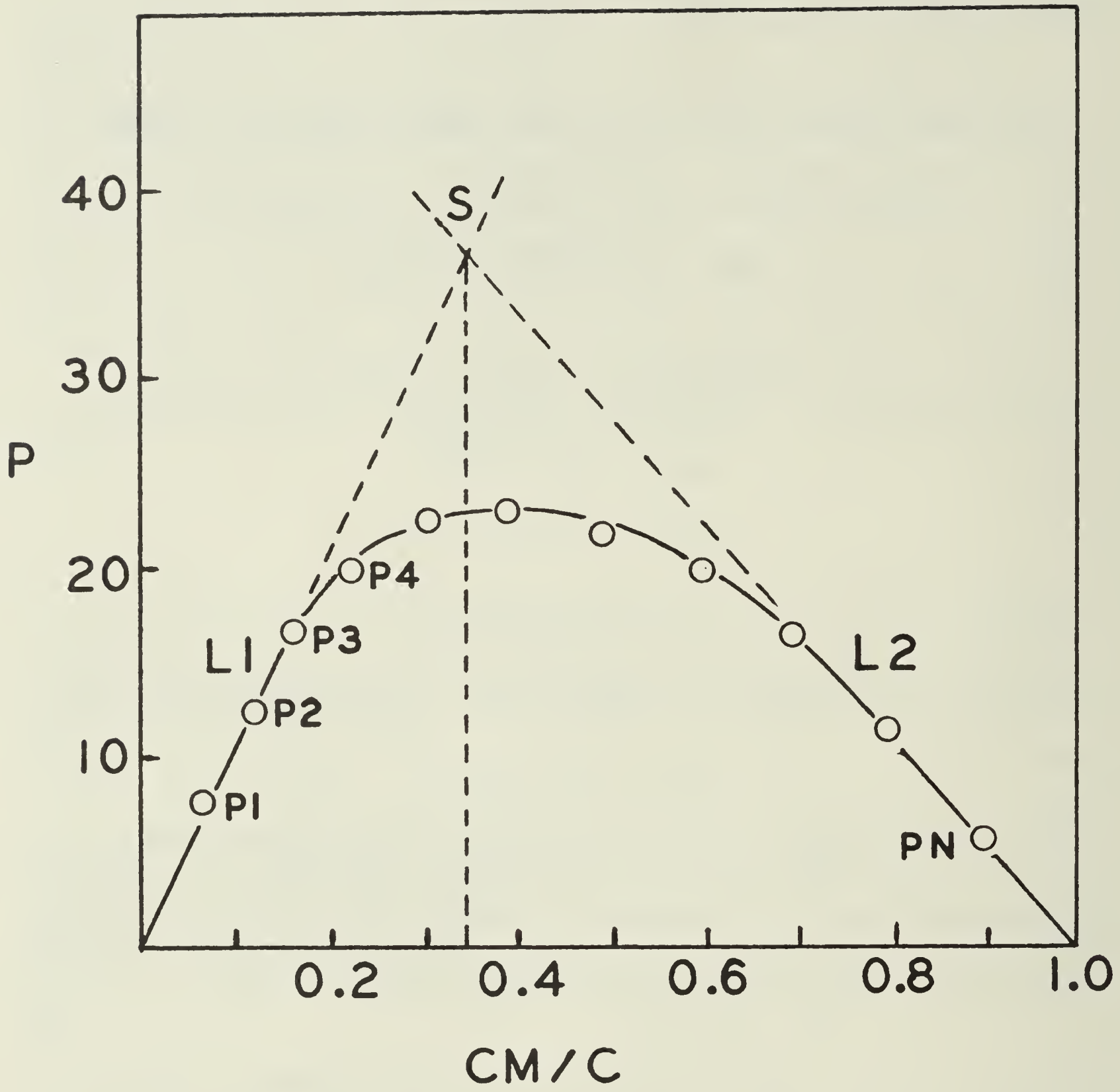

Fig. 1. A typical Job's plot.

simultaneously drawing the curves and locating the maximum using the intersection point of lines established using linear regression.

PRINCIPLES AND ALGORITHM

In practice, a curve from a Job's method plot may have a general shape like that shown in Figure 1. To determine the maximum, the first few data points for the lower CM_i values to the left of the maximum are considered to form one linear portion (L1) while those to the right are considered to form another (L2). The maximum is established by extending these two linear regions until they intersect at point S. A program for carrying out the procedure was written in BASIC for implementation on the Radio Shack PC-2 pocket computer and its graphics plotter. The program is divided into two sections. The first section includes a subroutine to perform linear regression and calculates the regression lines L1 and L2 as well as their point of intersection. The second section graphically illustrates the data used and draws the regression lines and the property vs. concentration curve.

In determining the regression lines, the computation is first carried out with the two data points for the lowest CM values (P1 and P2 of Figure 1) and establishes a linear fit having a correlation coefficient r for those two points. For only two data points, /r/ = 1 so the next higher CM data point (P3) is included. Linear regression is again performed and the value of /r/ is obtained. Now a sufficiency test for linearity is used in the form of a minimum correlation coefficient, D. If /r/ D, the next point is included and /r/ is again determined and compared to D. When adding one more point causes /r/ $<$D, the line L1 is not sufficiently close to linear, and the previous relationship for L1 is used. Thus, each slope and intercept must be saved until the subsequent cycle is complete. The linear relationship for L2 is established in a similar manner including as many data points as possible as long as /r/ $>$D. Thus, in the region L1,

$$P = m_1(CM) + b_1 \tag{2}$$

and in the region L2,

$$P = m_2(CM) + b_2 \tag{3}$$

where m_1 and m_2 are the slopes and b_1 and b_2 are the intercepts of the two lines. At the point of intersection,

$$CM = (b_2 - b_1)/(m_1 - m_2) \tag{4}$$

Now the ratio of metal to ligand in the complex, M/L, is given by CM/(C − CM) and the ratio of ligand to metal, L/M is given by (C − CM)/CM.

Having determined the composition of the complex, the program now executes the plotting procedure. First, coordinate axes are drawn and labeled, and the numerical values for D, S, and L/M are printed. With the frame in place, the data points are plotted as asterisks and they are connected with a solid line. Next, the dotted lines are drawn that show the linear relationships established for L1 and L2 using dat for which /r/ $>$D. Then, a vertical dotted line is drawn from the intersection point S to the concentration axis. A complete program listing and a data dictionary are given in the Appendix.

COMPUTATION

In order to show the input/output characteristics of the program, we present here an example computation. Table 1 shows the data used in this computation. The data are given in the program in lines 120-220.

Table 1. Data for program testing. Total concentration is 1.00 *M*.

CM, Moles/liter	P	CM, Moles/liter	P
0.065	7.4	0.500	21.0
0.110	12.5	0.600	18.5
0.160	18.0	0.695	17.0
0.210	19.4	0.790	11.3
0.300	22.0	0.900	5.2
0.402	21.9		

In the present case, the value of D = 1.00 was used first, assuming the L1 and L2 must have exactly a linear fit. Figure 2(a) shows the result obtained. Next, a value

of D = 0.99 was used with the result shown in Figure 2(b). Successively smaller values of D were used until a value of 0.90 was reached. While in this particular case the ratio L/M could be identified as 2, it is obvious (from Figure 2(f)) that a correlation coefficient of 0.90 does not provide a very good fit to the data. Unless the data are subject to large experimental errors, it appears that a D value of at least 0.98 should be chosen. It is, therefore, preferable to have a large number of data points and to have as accurate data as possible.

In using the program with other data, the value of D must be entered at line 100 and the number of data points must be entered at line 110. The data points used must be entered at lines 120-220.

Each of the diagrams shown in Figure 2(a)-(f) requires about 40 sec for the computation and drawing of the figure. Therefore, it is possible to apply Job's method in a much more convenient and rapid manner than has been available previously.

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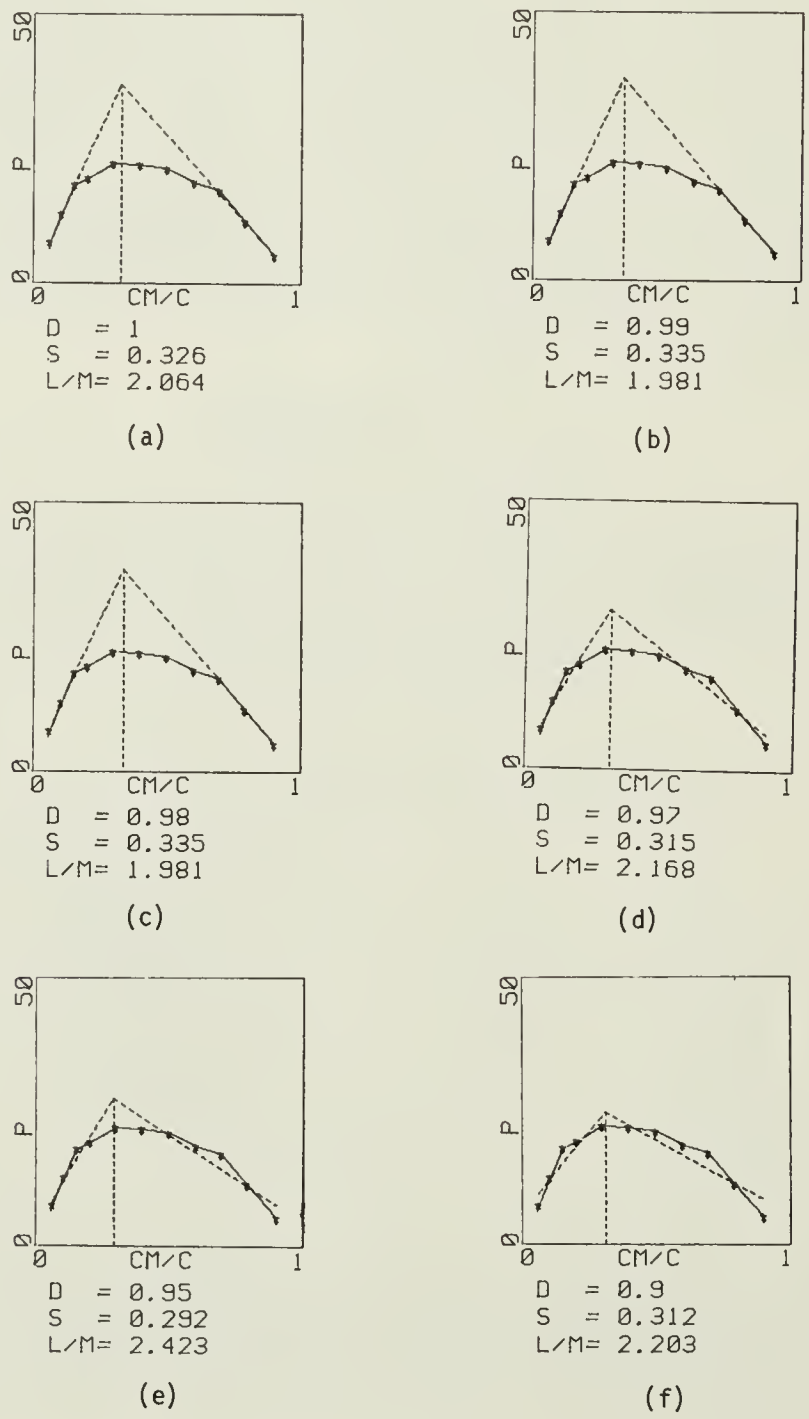

Fig. 2. Output obtained using data shown in Table 1.

APPENDIX

PROGRAM DATA DICTIONARY

Name	Description
BP	X coordinate of break point
CC	correlation coefficient
D1	domain lower bound
D2	domain upper bound
I	data element index
II	index increment
K	constant, value = 200
L	loop counter
LI	Y intercept for left correlation line
LS	slope for left correlation line
L1	loop counter 1
NE	number of elements used for corr. line
NP	number of data points
P	array of data points DIM (NP,2)
RI	Y intercept for right correlation line
RS	slope for right correlation line
R1	range lower bound
R2	range upper bound
S	slope of correlation line from subroutine
S1	sum of XY
S2	sum of X**2
S3	sum of Y**2
S4	sum of X
S5	sum of Y
X	X coordinate to be plotted
X1	last X coordinate plotted
Y	Y coordinate to be plotted
YI	Y intercept calculated in subroutine
Y1	last Y coordinate plotted

PROGRAM LISTING

```
100:DATA .99
110:DATA 11
120:DATA .065,7.4
130:DATA .110,12.5
140:DATA .160,18.0
150:DATA .210,19.4
160:DATA .300,22.0
170:DATA .402,21.9
180:DATA .500,21.0
190:DATA .600,18.5
200:DATA .695,17.0
210:DATA .790,11.3
220:DATA .900,5.2
230:READ D
240:READ NP
250:DIM P(NP,2)
260:FOR L=1TO NP
270:READ P(L,1)
280:READ P(L,2)
290:NEXT L
300:I=1
310:II=1
320:GOSUB 430
330:RS=S
340:RI=YI
350:I=NP
360:II=-1
370:GOSUB 430
380:LS=S
390:LI=YI
400:BP=(LI-RI)/(RS
    -LS)
410:PRINT "BP=";BP
420:GOTO 630
430:REM
     CORRELATION
        LINE
     SUBROUTINE
440:S1=0
450:S2=0
460:S3=0
470:S4=0
480:S5=0
490:NE=0
500:NE=NE+1
510:S1=S1+P(I,1)*P
    (I,2)
520:S2=S2+P(I,1)*P
    (I,1)
530:S3=S3+P(I,2)*P
    (I,2)
540:S4=S4+P(I,1)
550:S5=S5+P(I,2)
560:I=I+II
570:IF NE<2THEN
    GOTO 500
580:CC=ABS (NE*S1-
    S4*S5)/SQR((NE*S
    2-S4*S4)*(NE*S
    3-S5*S5))
590:IF CC<0THEN
    RETURN
600:S=(NE*S1-S4*S5
    )/(NE*S2-S4*S4
    )
610:YI=(S5-S*S4)/N
    E
620:GOTO 500
630:REM
     GRAPHIC PART
      OF PROGRAM
640:COLOR 0
650:CSIZE 2
660:GRAPH
670:GLCURSOR (16,-
    250)
680:SORGN
690:K=200
700:D1=0
710:D2=1
720:R1=0
730:R2=50
740:ROTATE 3:
    GLCURSOR (-3,0
    ):LPRINT "0
       P        50"
750:ROTATE 0:
    GLCURSOR (0,-1
    6):LPRINT "0
       CM/C       1
    "
760:LINE (0,0)-(K,
    K),0,,B
770:GLCURSOR (0,-4
    0):LPRINT " D
     =";D
780:GLCURSOR (0,-6
    0):LPRINT " S
     =";INT (BP*10
    00)/1000
790:GLCURSOR (0,-8
    0):LPRINT " L/
    M=";INT ((1-BP
    )/BP*1000)/100
    0
800:Y1=99999999
810:FOR L1=1TO NP
820:X=P(L1,1)
830:Y=P(L1,2)
840:IF Y>R2OR Y<R1
    OR Y1>R2OR Y1<
    R1THEN GOTO 87
    0
850:GLCURSOR ((X1-
    D1)/(D2-D1)*K,
    (Y1-R1)/(R2-R1
    )*K)
860:LINE -((X-D1)/
    (D2-D1)*K,(Y-R
    1)/(R2-R1)*K),
    0
870:CSIZE 1
880:GLCURSOR ((X-D
    1)/(D2-D1)*K-3
    ,(Y-R1)/(R2-R1
    )*K-4)
890:LPRINT "*"
900:X1=X
910:Y1=Y
920:NEXT L1
930:CSIZE 2
940:GLCURSOR ((P(1
    ,1)-D1)/(D2-D1
    )*K,(P(1,1)*RS
    +RI-R1)/(R2-R1
    )*K)
950:LINE -((BP-D1)
    /(D2-D1)*K,(BP
    *RS+RI-R1)/(R2
    -R1)*K),2
960:LINE -((P(NP,1
    )-D1)/(D2-D1)*
    K,(P(NP,1)*LS+
    LI-R1)/(R2-R1)
    *K)
970:GLCURSOR ((BP-
    D1)/(D2-D1)*K,
    (BP*RS+RI-R1)/
    (R2-R1)*K)
980:LINE -((BP-D1)
    /(D2-D1)*K,(0-
    R1)/(R2-R1)*K)
    ,2
```

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SCIRPUS MUCRONATUS AND *VALERIANELLA CHENOPODIFOLIA* IN ILLINOIS

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ABSTRACT

Scirpus mucronatus L., *Valerianella chenopodifolia* (Pursh) DC and *Picea abies* (L.) Karst. are reported as spontaneous in Illinois for the first time.

Voucher specimens of each of the species treated herein have been deposited in the Herbarium of the Illinois State Museum (ISM).

While collecting in the sand areas of western Mason County in 1975, I visited a large relatively low area about 1.3 miles southeast of Snicarte that was standing in water during this exceptionally wet summer. Although it was obvious that this entire area was cultivated in dry years, it was now covered with a carpet of the rarely encountered annual sedge *Scirpus hallii*. Scattered here and there were the peltate leaves of American lotus (*Nelumbo lutea*) attesting to the more permanent wetland nature of the site in presettlement times. Also scattered throughout the site were clumps of a perennial *Scirpus* about 7 dm tall that were completely new to me. This new *Scirpus* did not readily key to any species in the manuals at hand, but I finally decided I had found a rare inland population of the coastal *Scirpus olneyi*. The site was completely farmed in succeeding years but the strange sedge reappeared in wet summers in 1979 and 1981. Not satisfied with my earlier identification, I sent specimens to *Scirpus* authority Dr. Alfred E. Schuyler at the Philadelphia Academy of Natural Sciences. Dr. Schuyler identified the plant as *S. mucronatus*, a European species that is established in California and which has occasionally turned up elsewhere in the United States.

Since *S. mucronatus* is not adequately described in the manuals for our range, a brief description here seems appropriate. It is perennial from short rhizomes giving older plants a clumped appearance. It apparently fruits as a one year old plant only a decimeter or two high, at which time it could be mistaken for an annual. As the plant matures, it reaches a height of about 7 dm. and its clumps have a peculiar flat-topped appearance due to the involucral bracts, up to 10 cm. long, which are deflexed at right angles to the stem. Culms are sharply triangular and slightly

winged on the angles, up to 8 mm wide when pressed, and weak and spongy in texture. Spikelets number up to 17 and probably more per inflorescence and achenes are planoconvex.

I believe that S. mucronatus arrived at its Illinois locality by natural means, probably on the feet of birds. The source area and time of introduction are unknown. The sand area in which it grows harbors a variety of greatly disjunct species of which four are moist soil sedges (Winterringer 1959). These sedges are *Fimbristylis vahlii*, *Scleria reticularis*, *Scirpus hallii* and *Lipocarpha maculata*. Apparently sand areas provide an exceptional environment for establishment of long range migrants. It is possible that *S. mucronatus* has been in Illinois since presettlement times and has not spread significantly because of the very limited nature of its specialized habitat.

Collection data on my voucher specimen are as follows: open sandy marsh southeast of Snicarte, Mason County, Illinois; July 18, 1975; John Schwegman #2642.

Valerianella chenopodifoloia has a restricted range in the upper midwest, ranging from southern Ontario and western Pennsylvania to Wisconsin. The closest previous report to Illinois is by Swink and Wilhelm (1979) from LaPorte County, Indiana. I discovered this species on a south-facing, low bluff of limestone fronting on the Des Plaines River in Will County. It was locally very abundant in this small area of habitat. Collection data: rocky limestone slopes along north side of Des Plaines River 3.5 miles below the Brandon Locks at Joliet, Will County, Illinois; May 18, 1982; John Schwegman #3098.

Picea abies, the Norway spruce, is widely cultivated but rarely reported as escaping into wild situations. I was very surprised to find a sapling of this species in a very natural setting on a steep north-facing bluff along the Galena River in JoDaviess County. It was growing at the base of a shaded slope in a large stand of yew (*Taxus canadensis*) where it had apparently seeded in naturally from trees in a nearby cemetery. Collection data: base of steep north-facing bluff along Galena River below Grant Hill Cemetery, 4½ miles northeast of Galena, JoDaviess County, Illinois; September 13, 1981; John Schwegman #3063.

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PROTEIN BODY AND CELL WALL DEVELOPMENT IN SOYBEAN COTYLEDONS

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ABSTRACT

Cell wall and protein body development were examined in three planes of section from samples taken during the linear phase of growth, 5 through 11 mm seed length (14 to 24 days after anthesis). Cells sectioned radially or longitudinally were elongate, but were circular in transverse section (perpendicular to the flat interior surface of the cotyledon in the seed). No mitotic figures were found. Protein bodies formed first in the subepidermal layer of palisade cells and in cells surrounding the vascular tissue, generally with one major body per cell. The major protein body enlarged, retaining the general shape of the elongating cell, with numerous small protein bodies forming on the periphery of the central vacuole. The ability of the cells to imbibe water was correlated with the rapid increase in cell wall thickness as the growth rate declined and the green seeds entered the maturation phase.

INTRODUCTION

Bils and Howell (1963) found that the nucleus is the most prominent structure in the parenchyma cells of young cotyledons, although a few proplastids, mitochondria and "ribonucleoprotein particles" are present. Cell division ceases by 15 days following anthesis (Mori, et al., 1978). An obvious vacuole becomes visible by day 18 with lipid granules, immature chloroplasts, starch particles and numerous mitochondria visible within the cytoplasm. A few large protein bodies are present by day 26 and the size of these bodies increases rapidly as the cell volume increases tenfold over the next 10 days (Bils and Howell, 1963). Storage proteins, once synthesized, do not break down during soybean seed formation (Madison, et al., 1981). This paper examines protein body and cell wall development during the stage of rapid cell enlargement.

MATERIALS AND METHODS

Seeds of soybean (*Glycine max* L. Merr. var. Williams) were planted June 5, 1979 at the Western Illinois University Experimental Farm. Twenty plants were selected at developmental stage R8, using the scheme developed by Fehr, et al. (1971). The lowermost flowering node of these plants was tagged and observed. One seed per pod was measured every two days along the longest axis from the time pods developed with seeds measuring 5 mm in length until the stationary phase was reached. Measurements were made while the seeds were in the attached pods by illuminating the pods and measuring the outline of the seeds within the pod using a vernier caliper.

Ten soybean seeds were harvested at four different stages of development (5.0, 7.0, 9.0, and 11.0 mm seed lengths). One of the two cotyledons from each seed was sectioned radially and longitudinally. A transverse section was obtained from the other cotyledon of the pair (Fig. 1). The tissues were immediately fixed in 3% glutaraldehyde in 0.05 M PO_4, pH 6.8 for 1 1/2 hours. The fixative was aspirated and the tissue was rinsed three times in 0.05 M PO_4, pH 6.8 for a total of 1 hour immersion. Postfixation was accomplished using 2% OsO_4 (0.05M PO_4) for 2 hours. The OsO_4 was aspirated and the tissue was rinsed in 0.05 M PO_4. Fresh buffer was added and the tissue was stored at 15° C.

Dehydration of the sections was accomplished using an ethanol series (35, 50, 70, 95, and 100%), and then cleared by 10 min immersion in a series of ethanol:xylene mixtures (2:1, 1:1 and 1:2) followed by 100% xylene. The sections were infiltrated with paraffin in a vacuum oven with paraffin changes at 1 1/2 hour and 1/2 hour intervals. Paraffin sections 10 microns thick were cut using a microtome, and transferred to albumin-treated slides. Slides were dried overnight and treated to two 10 min changes of xylene, followed by an ethanol series (100, 95, 70, and 35% mixtures, 2 min each); 10% mercuric bromophenol blue (15 min); 0.5% acetic acid (20 min); an ethanol series (35 and 70% ethanol, 30 sec each, followed by a 20 sec exposure to 95%, and a 2 min exposure to absolute ethanol); and xylene (two changes, 10 min and 5 min). Sections were permanently mounted using Canadian Balsam and photographed using a Zeiss microscope fitted with a phase-contrast 25x objective. Copies of all photographs were analyzed to determine cell number, wall thickness, maximum protein body diameter, number of protein bodies per cell, and cell number per mm^2.

The water content of other cotyledon samples was determined at each of the developmental stages by removing and weighing one cotyledon of each pair, drying it at 100°C, and reweighing it. The other cotyledon of the pair was weighed and then transferred to tap water for 48 hrs. The fully imbibed cotyledons were blotted, reweighed, and also dried. Water contents were expressed as the difference between the fresh and imbibed weight and weight after drying at 100° C.

RESULTS AND CONCLUSIONS

The increase in seed length described a sigmoid curve (Fig. 2). Samples were harvested during the linear phase, between seed lengths of 5.0 and 11.0 mm, and during the stationary phase after the seed exceeded 11.0 mm in length but before dessication at maturity resulted in a decrease in seed length. No mitotic figures were observed; growth was therefore a function of cell enlargement rather than

cell division. Parenchyma cells of the cotyledons sampled at 5 mm length were approximately isodiametric in transverse section (Fig. 3), and elongate in longitudinal and radial section (Figs. 4 and 5). As the cotyledon length increased, cells enlarged in all directions.

Protein bodies formed first in areas close to or in the developing vascular tissue, and in a subepidermal area on the adaxial surface in the same manner as reported by Graham and Gunning in *Vicia faba* (1970). Protein bodies were present in the epidermal layer, although to a lesser extent than in the subepidermal layer.

A highly uniform population of protein bodies was present in the palisade layer of cotyledons 5.0 mm in length (Fig. 6). Each palisade cell contained one centrally-located protein body supported by cytoplasmic strands. Protein bodies first appeared near the plasmalemma in the youngest cotyledons sampled (5 mm). The protein bodies were spherical in all planes of section, and were approximately 4.7 microns in diameter. Most cells contained one protein body at this stage of development.

The dimensional changes in protein bodies during development are summarized in Table 1. The primary protein body increased in size to a mean diameter of 5.6 microns in cotyledons of seeds 7 mm long with additional, small protein bodies occurring within the cytoplasm (Fig. 7). The primary protein bodies retained their spherical shape in transverse section. However, the protein bodies changed from a spherical to an ellipsoid shape, conforming to changes in the shape of the cells containing them. No fusion of protein bodies was observed. Transverse sections of cells showed spherical protein bodies, although in some cases their shape was distorted by other protein deposits as the cells matured. The mean diameter of the principal protein bodies was 10 microns in 9 mm seeds, and they were ellipsoid in radial and longitudinal sections with a long axis of 11.0 microns. Storage protein deposition continued throughout cell enlargement, until protein bodies and cell walls were the dominant features in sections taken from green cotyledons after they had reached their maximum length of 11 mm (Figs. 8-10).

Cell wall apposition contributed greatly to total seed volume as the seed matured. Cell walls were indistinguishable from cytoplasm adjacent to the plasma membrane in sections taken from the 5.0 mm seed length samples. Cell wall deposition was evident at the seed length of 7 mm, with a mean thickness of 0.7 microns between adjacent protoplasts. Cell walls continued to thicken as the seed elongated; at 9.0 mm seed length the mean wall thickness was 3.1 microns and at 11.0 mm seed length it was 4.7 microns. Walls began thickening first on the abaxial side of the cotyledon. The increase in cell wall thickness is proportional to the ability of these green seeds to imbibe water (Fig. 11). This study suggests that cell wall thickness may be an important factor in seed germination. The relationships between cell wall mass and germinability deserve further study.

ACKNOWLEDGEMENT

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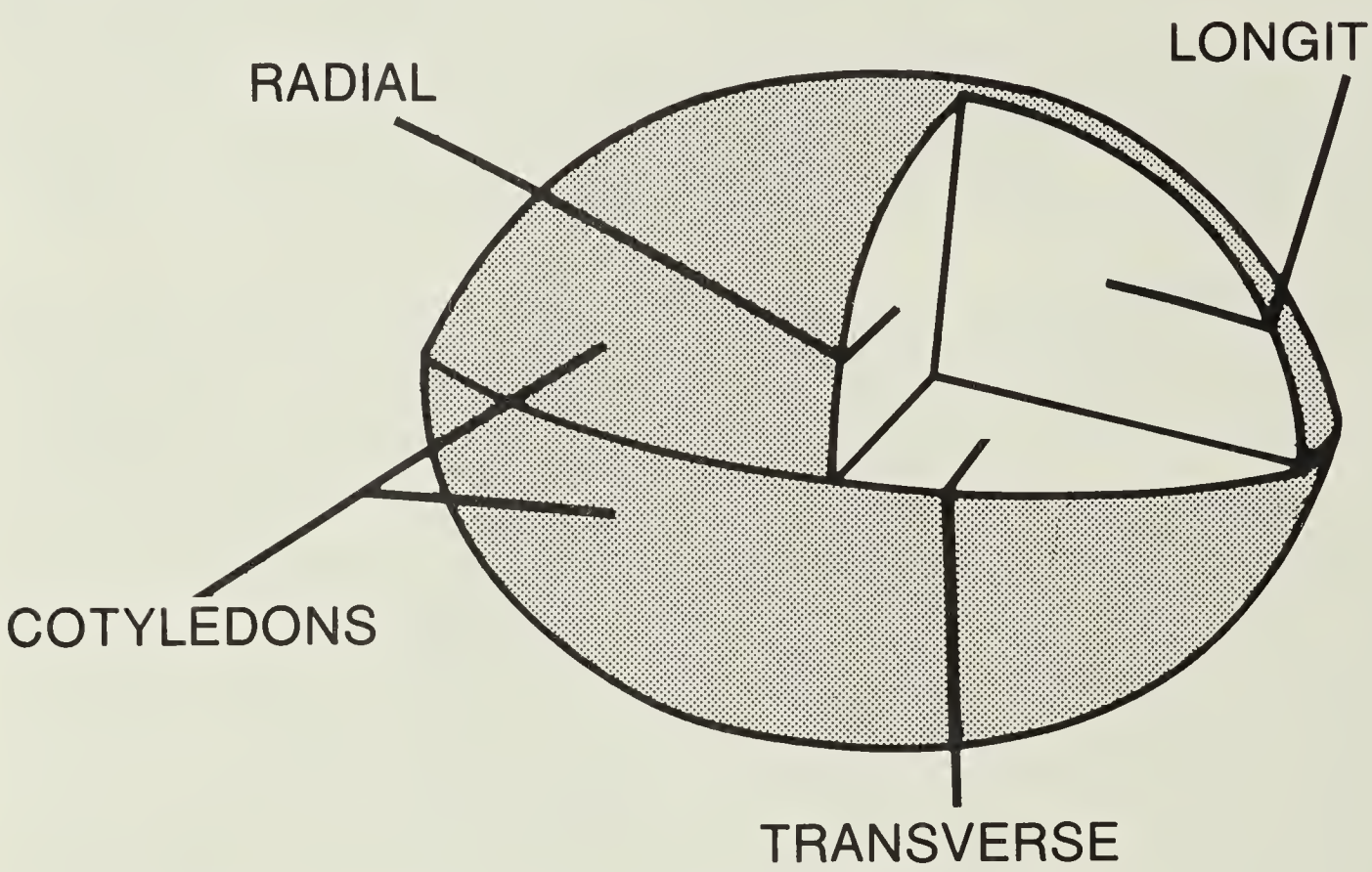


Fig. 1. Sectioned planes of the soybean cotyledon.

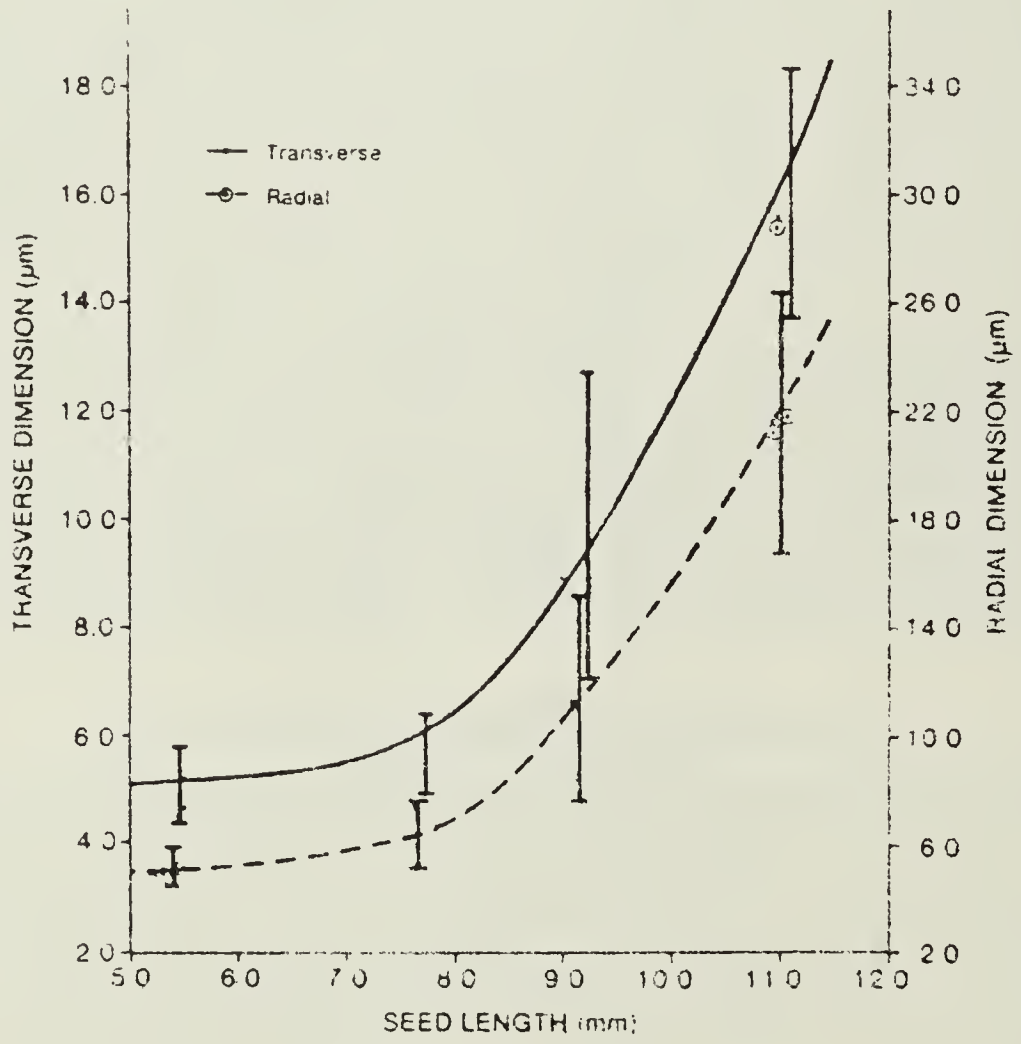
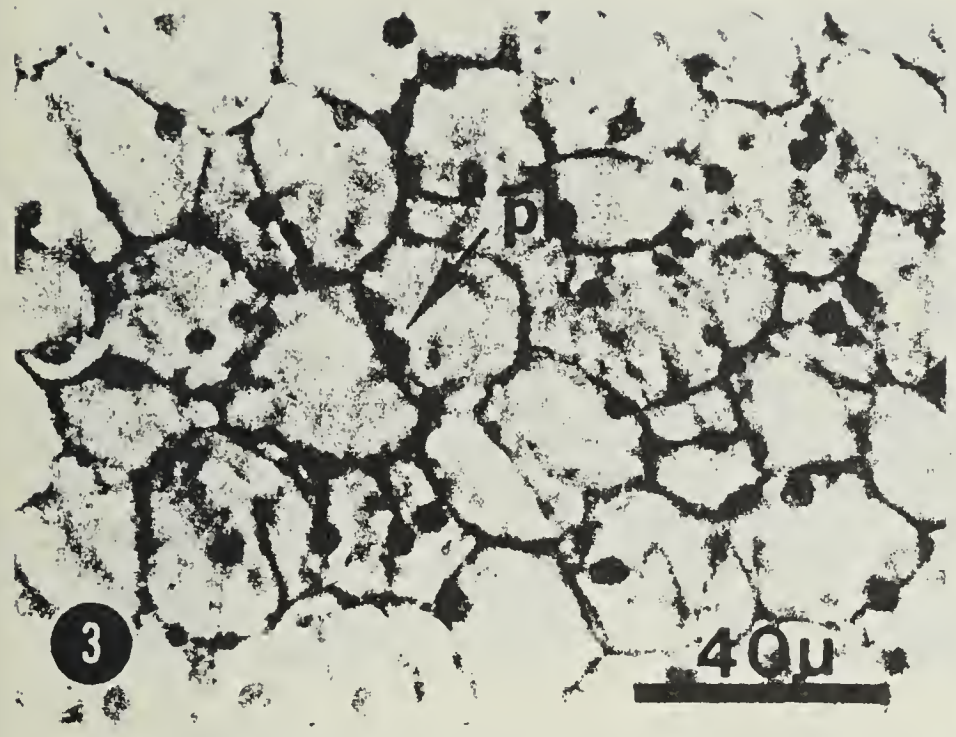


Fig. 2. Growth curve of the developing soybean cotyledon. Vertical bars represent standard deviation about the mean.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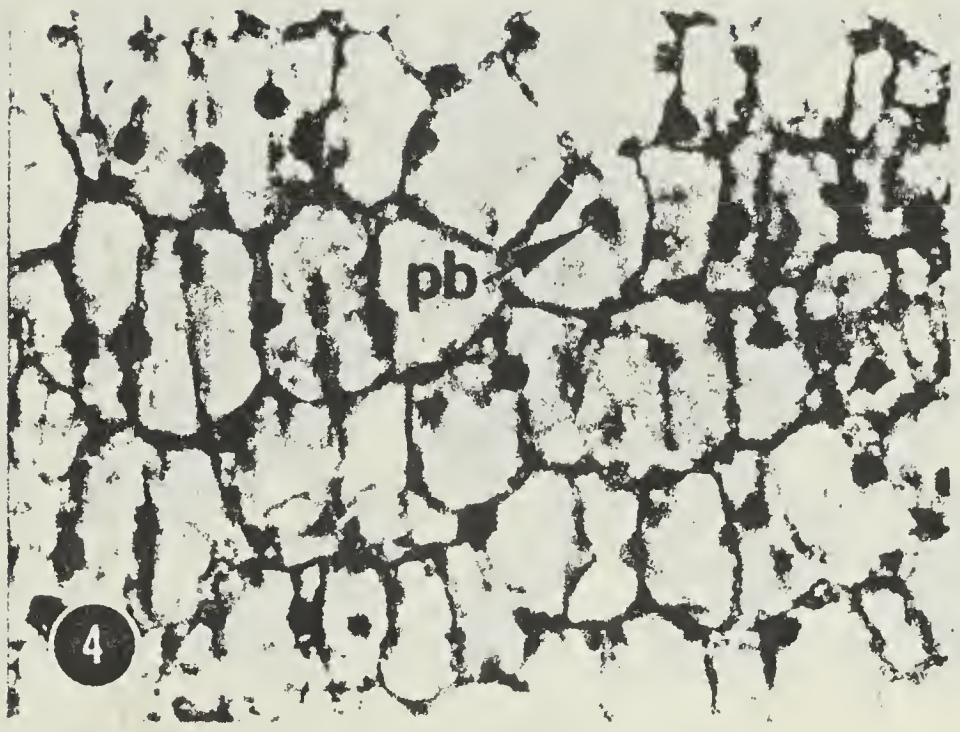
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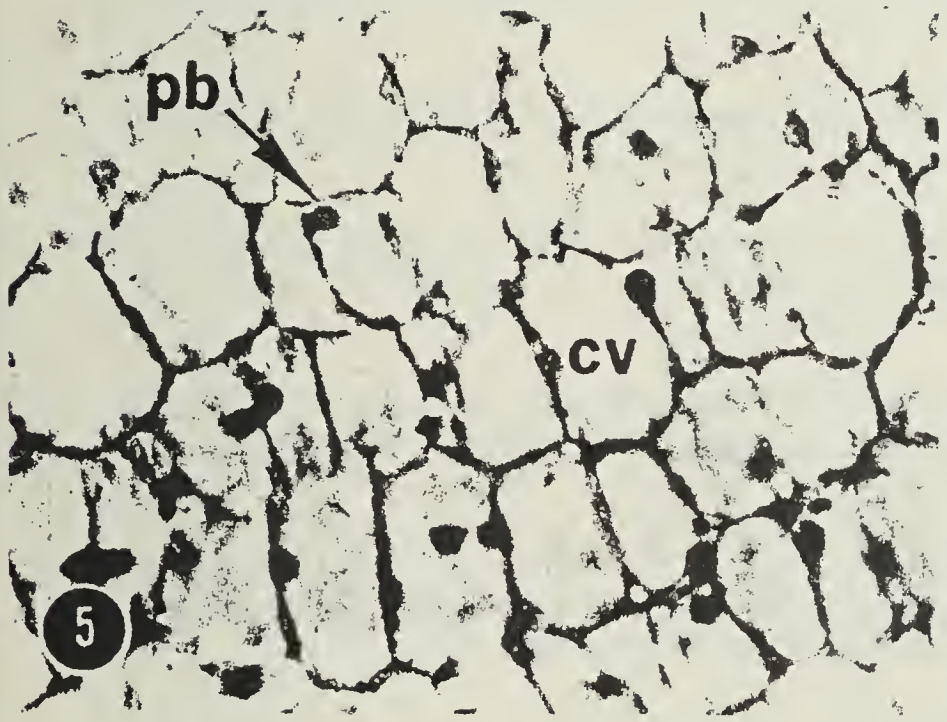
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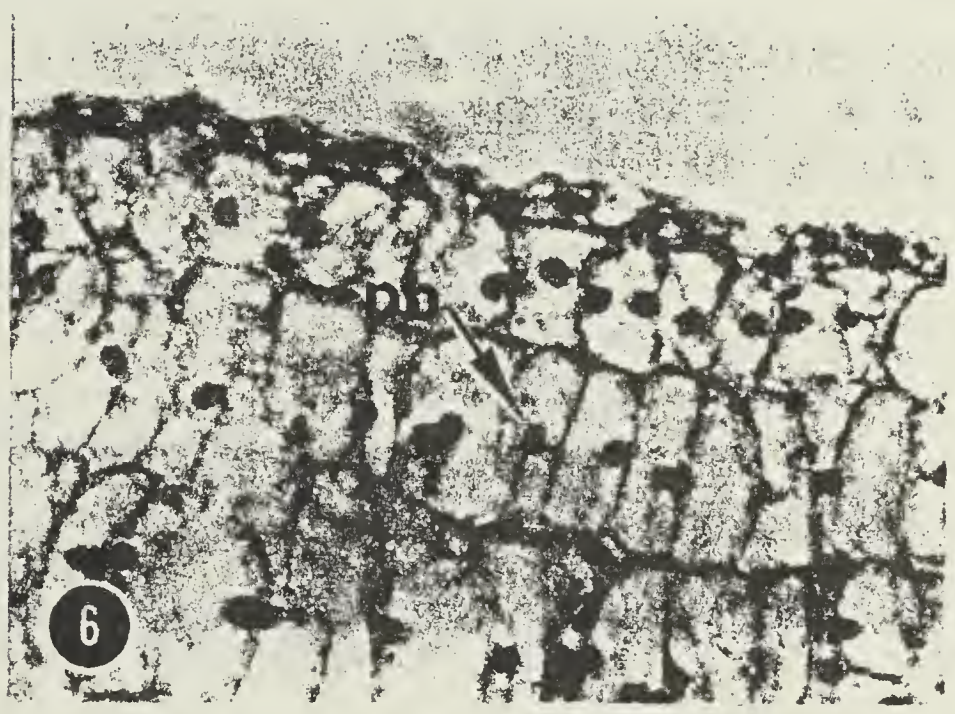
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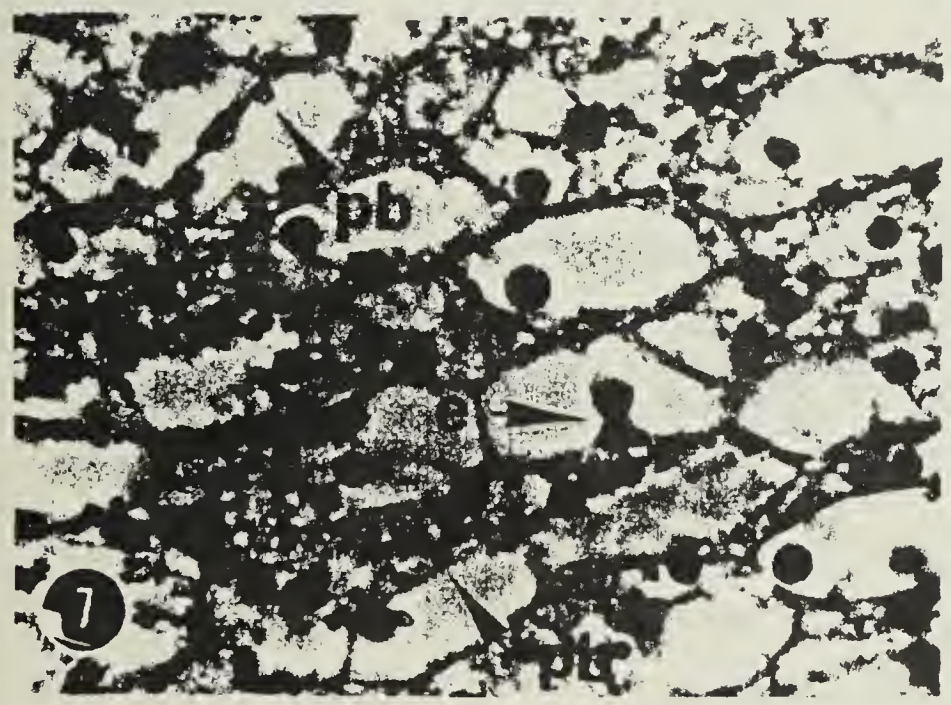
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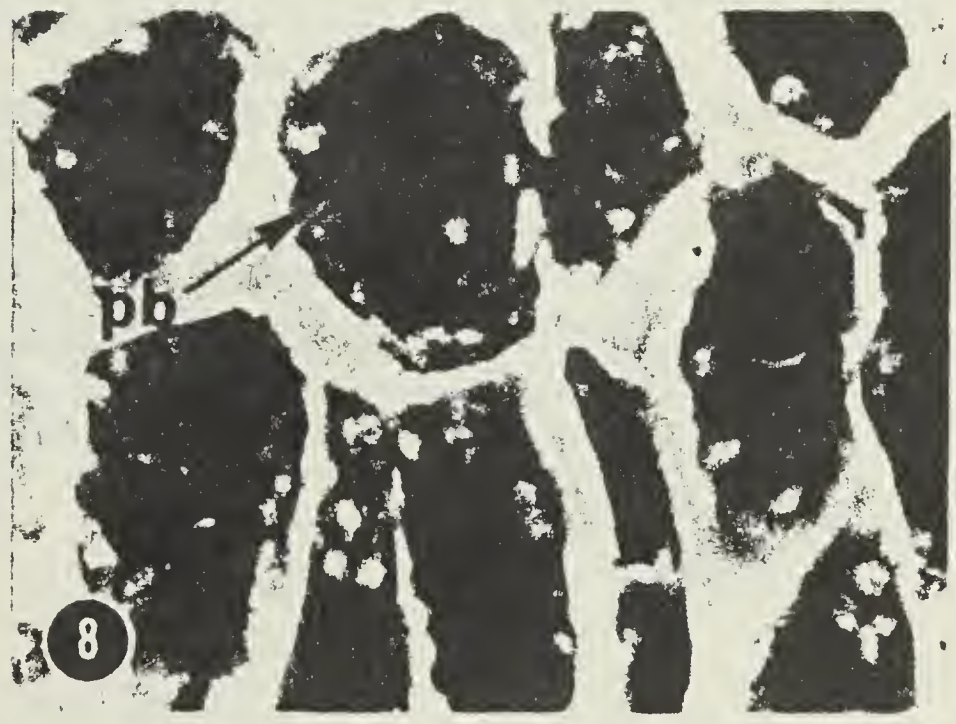
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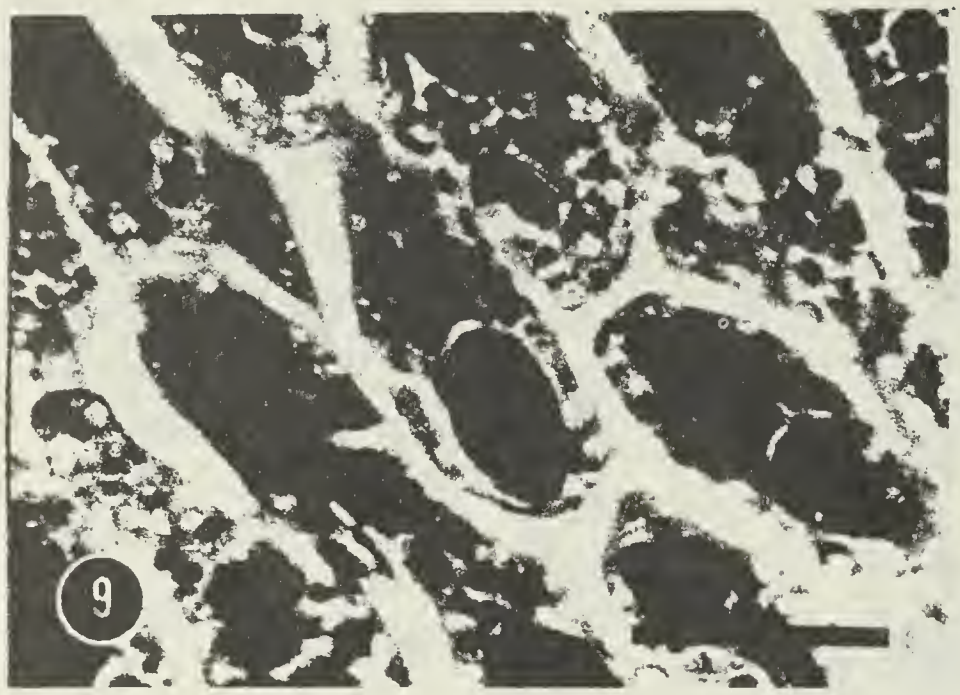

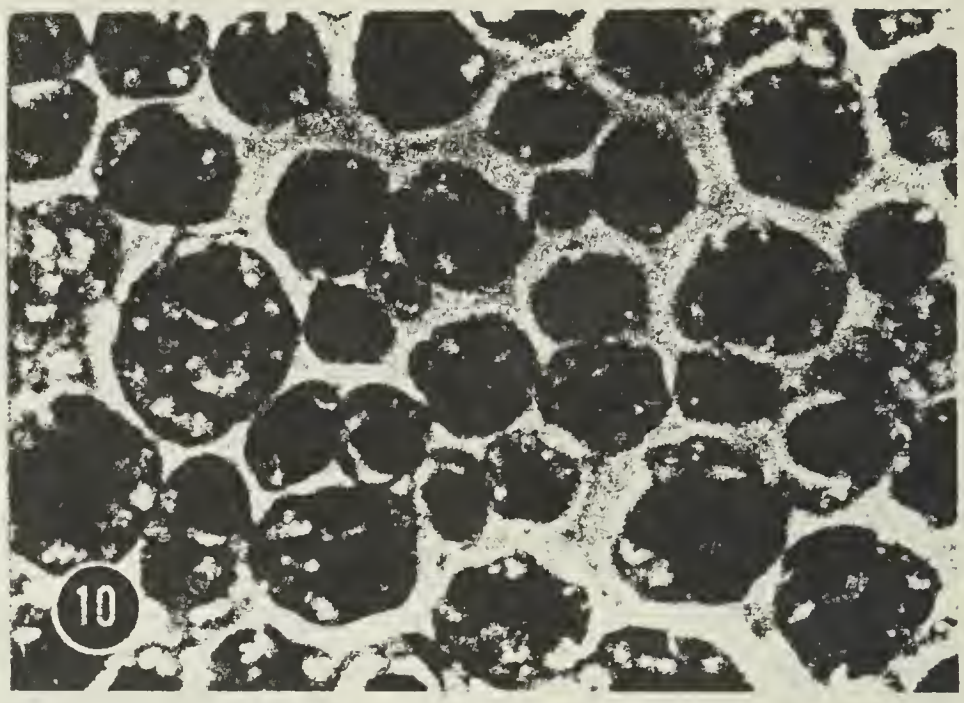

Fig. 3. Parenchyma cells exposed in transverse section in a cotyledon 5.0 mm in length. Approximately one major protein body can be seen between the central vacuole and cell membrane in each cell. Protein body: pb.

Fig. 4. Parenchyma cells exposed in radial section in a cotyledon 5.0 mm in length. Slightly elongated cells containing one major protein body are present. Protein body: pb.

Fig. 5. Parenchyma cells exposed in longitudinal section in a cotyledon 5.0 mm in length. The central vacuole and the protein body are the dominant cellular features. Central vacuole: cv. Protein body: pb.

Fig. 6. Epidermal and palisade layers of longitudinally sectioned cotyledons 5.0 mm in length. A highly uniform population of protein bodies is present on the adaxial surface of the soybean cotyledon. Protein body: pb.

Fig. 7. Parenchyma cells exposed in radial section in a cotyledon 7.0 mm in length. Small protein bodies are seen developing within the cytoplasm and an evagination of the central vacuole containing proteinaceous material is present. Protein body: pb. evagination: e.

Fig. 8. Parenchyma cells exposed in radial section in a cotyledon 11.0 mm in length. Elongated cells with tapered ends are filled with darkly stained proteinaceous material and surrounded by thick cell walls. Protein body: pb.
Note: All photographs are taken at the same magnification. Two centimeters represents 40 microns.

Fig. 9. Parenchyma cells exposed in longitudinal section in a cotyledon 11.0 mm in length. Elongated cells with tapered ends are filled with proteinaceous material and surrounded by thick cell walls.

Fig. 10. Parenchyma cells exposed in transverse section in a cotyledon 11.0 mm in length. Cells spherical in shape are filled with proteinaceous material and surrounded by thick cell walls.
Note: All photographs are taken at the same magnification. Two centimeters represent 40 microns.

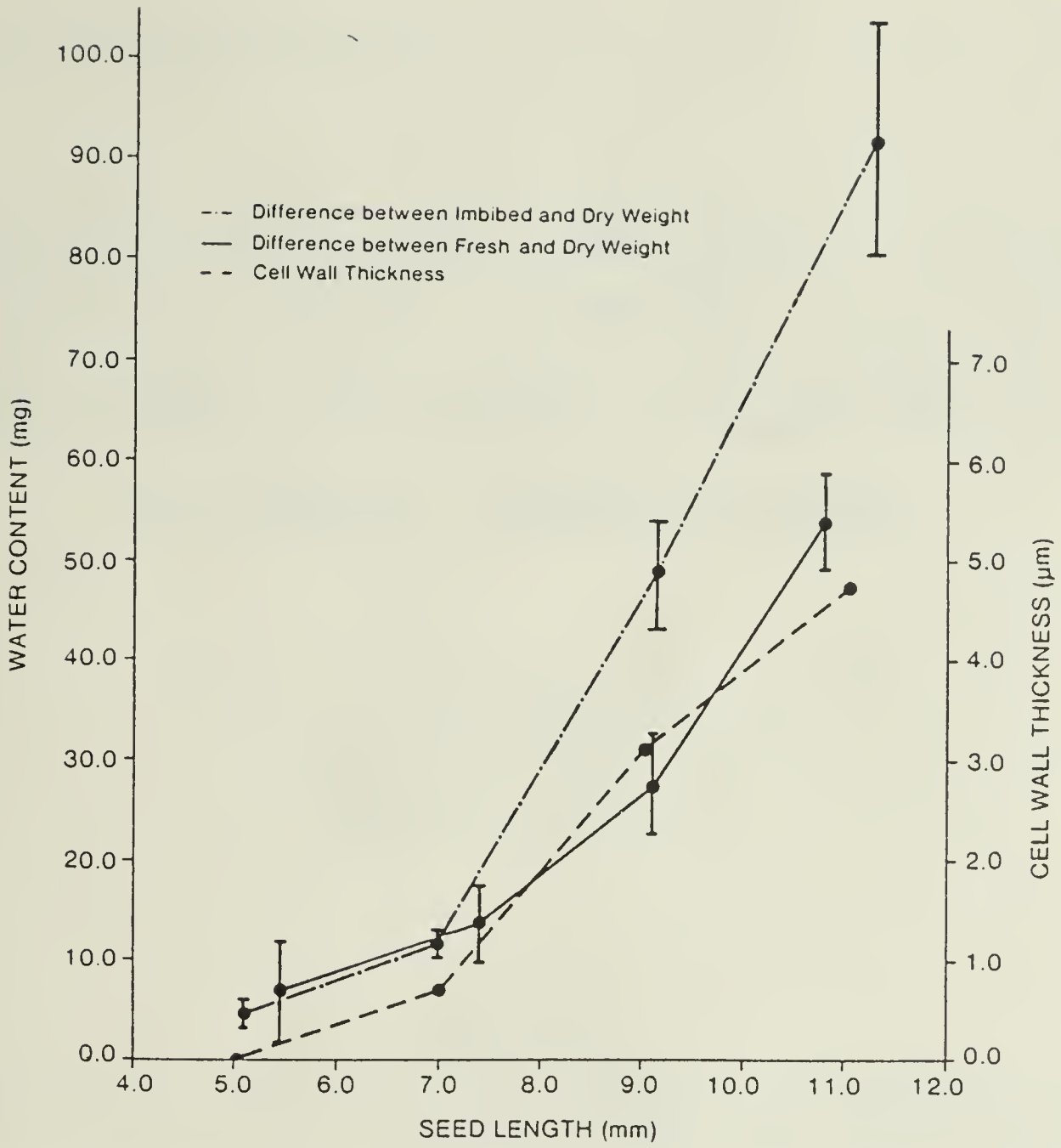

Fig. 11. Relationship between cell wall thickness and water content of the developing soybean cotyledon. Vertical bars represent standard deviation about the mean.

Table 1. Number of Major Protein Bodies per Cell Visible in Three Planes of Section at Four Stages of Cotyledon Development.

Mean Seed Length (mm)	Number of Major Protein Bodies per Cell*		
	Transverse	Radial	Longitudinal
5.44	0.49 ± 0.10	0.58 ± 0.18	0.52 ± 0.12
7.70	0.42 ± 0.11	0.91 ± 0.33	0.57 ± 0.13
9.24	0.40 ± 0.05	0.79 ± 0.20	0.69 ± 0.10
11.08	0.55 ± 0.11	0.69 ± 0.33	0.59 ± 0.23

*Expressed as a mean ± one standard deviation.

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AN ASSESSMENT OF THE FISH FAUNA OF LAKE CALUMET AND ITS ADJACENT WETLANDS, CHICAGO, ILLINOIS: PAST, PRESENT, AND FUTURE

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ABSTRACT

A survey of the fishes of Lake Calumet and its adjacent wetlands was conducted from September 1981 through August, 1982. A total of 27 fish species from 10 different families was collected within the entire area sampled. Twenty-six of these species were present in Lake Calumet and eight from the wetlands east of Lake Calumet. Comparisons of present species composition with historical records have shown a number of species previously occurring in the lake appear to have been extirpated. The fish community in Lake Calumet is nonetheless relatively diverse. The quality of fish faunas within various subsections of the lake was assessed using Karr's (1981) index and related to habitat modification.

INTRODUCTION

Lake Calumet, in Chicago, is the largest body of water in Cook County that is located west of Lake Michigan. This lake and its adjacent wetlands remained relatively undisturbed by human activity until about 1930 when mining for beach sand was undertaken and filling activities in the north edge of the marsh began (Beecher, 1981). Since that time the area has been greatly modified with extensive dredging and filling activities, so that now the east shore contains several large slips. In addition, two dikes have been placed across the lake (Figure 1).

Published information relating to the fish fauna of Lake Calumet or the adjacent wetlands appears to be scant (Table 1). Slightly more general information is available for some portions of the Calumet River and surrounding areas. The

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earliest report was that of Nelson (1876) who reported nine fish species from the Calumet River. Meek and Hildebrand (1910) reported fishes known to occur in Lake Calumet (3 species) and the Calumet River (9 sp.). Less specific information concerning fish species from the Lake Calumet area may be obtained from examining distribution maps for various fish species in Illinois. The early Illinois survey of Forbes and Richardson (1920) recorded a total of 31 fish species in the general area around Lake Calumet. Woods and Beecher (unpublished) collected eight species in Lake Calumet in 1941 and deposited their collections at the Field Museum of Natural History, Chicago. Information on the fish fauna of Lake Calumet was published by Vidal and Wight (1975) in a review of the Cook County Surface Water Resources. Two fish samples were reported, one taken in 1952 (11 sp.) and the other in 1970 (10 sp.). Dennison (1978) prepared a survey of the fishes of Northeastern Illinois streams and included two stations on the Calumet River in the general vicinity of Lake Calumet. The first was on the east bank of the Calumet River at 130th Street, and contained two species. The second station was 2,000 feet north of O'Brien Lock and Dam, and contained 13 species (combined in Table 1). The most recent information on the general area of Lake Calumet is that obtained as a result of contract between the Metropolitan Sanitary District of Greater Chicago and Chicago District of the U.S. Army Corps of Engineers (Polls *et al.*, 1980). Although no samples were taken either within Lake Calumet proper or the wetlands in the general vicinity, samples were taken at the southern end of the lake where it joins the Calumet River at Turning Basin Number five, just north of 130th Street, and at several localities on the Calumet River between that site and Lake Michigan. Seventeen species were recorded from Turning Basin Number five.

Because of the uniqueness of this wetland area within the Chicago City limits, the availability of information of fish species present prior to disturbances, and the possibility of future developments that might affect the Lake Calumet fish fauna, a study was undertaken to determine the present composition of that fish fauna.

METHODS

Collections were made on the following dates: 4 & 5 September 1981; 21 & 24 May 1982; 22 & 23 June 1982; 15, 16, 20 & 23 July 1982; 11 & 12 August 1982. Collections were made using a 15-meter bag seine with 11-mm mesh wings and a 5-mm mesh bag, a 7.6-meter bag seine with a 5-mm mesh, or a 4.6-meter minnow seine with a 2-mm mesh. In addition, electrofishing was conducted using a Coffelt Electro-Shocker, AC current, 125-250 volts. Specimens either were preserved in a 10 percent formalin solution in the field, returned to the laboratory, washed in water and transferred to 40 percent isopropyl alcohol or, if readily identifiable in the field, were returned to the water. In the laboratory, specimens were identified using Smith (1979).

Representative samples of fish species collected have been deposited at the Field Museum of Natural History, the Illinois Natural History Survey and the Northern Illinois University fish museum collection.

Scientific names of fish species are listed in Tables 1 & 2, thus common names are used throughout the report.

Collections were made at the following localities having a fish fauna within the wetlands adjacent to the Lake Calumet: four ponds south of 122nd Street, east

of Stony Island Avenue and nòrth of Turning Basin No. 5; a canal directly east of the Norfolk and Western Railroad tracks between 116th and 122nd streets and two ponds located directly east of the canal and to the west of Torrence Avenue; wetland area bounded by Stony Island Avenue on the west, 110th Street on the north, 116th Street on the south and the Norfolk and Western Railroad tracks on the east; wetland area east of Stony Island Ave, north of 110th Street, south of 103rd Street and the Norfolk and Western Railroad yard on the east. Because several of these sites were modified during the course of this study, and others have been modified since the study was completed, the fishes collected at particular localities will not be reported separately, but will be reported as from "Adjacent Wetlands."

For purposes of sampling, Lake Calumet was divided into nine subsections (Sampling Sites) (Figure 1). Because of extensive filling activities, most of the shoreline of the lake consisted of cement rubble. In some areas, soil was dumped or graded over the rubble and terrestrial vegetation was estabilished. Along the south and east shores of the lake, large slips have been dredged to accommodate shipping. Much of the shoreline in these areas consisted of steep walls of wood or metal. The depth throughout the lake varied greatly. Much of the area was relatively shallow (2.0 meters); however, a number of areas had been dredged to depths as great as 10 meters. The bottom appeared to be soft mud in most areas.

Sampling Site 1 - This is the northernmost section of Lake Calumet, bounded by a dike on the south, that has a small break (approximately 1 meter wide; July 1982) allowing a flow of water from this area to the south. The shoreline bounding this subsection was cement rubble except for the northern shore where the fill is soil. About 8 acres (3.2 ha) of emergent vegetation extended into the water at the northern part of the area. Most of this area was relatively deep, exceeding 2 meters. This area was sampled during May, July and August.

Sampling Site 2 - This is the western part of Lake Calumet directly south of Sampling Site 1, bounded by the dike to the north and a second dike to the south. The southern dike had an opening approximately 10 meters wide, allowing exchange of water between Sampling Site 2 and areas to the south. Depending upon the relative water levels and/or wind velocity, there may be a strong current flowing in either direction through this opening in the dike. The shoreline of this area was mostly cement rubble, with small sand/mud beaches present at scattered localities. Small amounts of vegetation were present at scattered localities along the shoreline. Most of this area was relatively shallow, averaging around 1.5 meters. This site was sampled in July.

Sampling Site 3 - This is the portion of the lake directly east of Sampling Site 2. This site had a spit of land extending out into the lake from the eastern shoreline. North of the spit was a long beach extending north to the dike separating Sampling Sites 1 and 3. South of the spit was an inlet that bordered on the southern dike. The inlet carried discharge from adjacent wetlands through a culvert under the proposed Stony Island Ave. Extension. This created a microhabitat different from other portions of Sampling Site 3. The average depth of 3 was 1.5 meters. This site was sampled during July and August.

Sampling Site 4 - This site is along the western shore of the lake south of the dike forming the southern border of Sampling Site 2 and north of a line extending from the northern tip of an island located near the eastern side of the lake. This

area includes a canal that parallels the Calumet Expressway Frontage Road and enters the lake just south of the dike separating sites 2 and 3 from 4. Sampling was conducted in the canal and where it empties into the lake. Depth in this area averaged around 1.5 meters. This site was sampled in July and September.

Sampling Site 5 - This area includes the eastern shore of the lake south of the dike separating sites 2 and 3 from 4 and 5. It includes the area just south of the dike with a depth of 2.0 meters and the slip to the south with depths in excess of 2.0 meters. The shoreline was mostly cement rubble. This site was sampled in July.

Sampling Site 6 - This site is located on the eastern shore of the lake directly south of site 5, and includes a large slip opposite the island. The shoreline was mostly cement rubble except at the eastern end of the slip where vegetation was present. The depth was greater than 2.0 meters. This area was sampled once in July.

Sampling Site 7 - This site represents the western shoreline of the lake south of site 4. The area had considerable soil pushed over the cement rubble, allowing for development of vegetation. The substrate was soft mud and water depth was shallow, about 1.5 meters or less. The area was sampled once in August.

Sampling Site 8 - This site is along the western shoreline of the island that runs north-south near the east shore of the lake. The water was shallow, less than 1.5 meters, the bottom was soft mud and the shoreline had dense stands of vegetation. This area was sampled once in July.

Sampling Site 9 (Turning Basin Number 5) - This site is located at the southern end of Lake Calumet where it joins the Calumet River. Sampling was conducted along the north shore where the water was shallow (1.5 meters or less) and the bottom a mixture of mud and gravel. This site was sampled during June and August.

RESULTS AND DISCUSSION

A total of 27 fish species from 10 different families was collected within the entire area sampled (Table 2). Twenty-six of these species were present in Lake Calumet and eight from the wetlands east of Lake Calumet. There was a maximum of five species at a single site within the wetlands. One species, the central mudminnow, was collected only in the adjacent wetlands and not in Lake Calumet. Within Lake Calumet there was a maximum of 16 species at any single site. An additional species, the chinook salmon, was present in the fall. No endangered or threatened species were collected or observed in the area sampled.

Young-of-the-year, as well as individuals of assorted sizes, of all eight species present in the adjacent wetlands were taken, indicating reproduction was occurring in those areas. Lake Calumet is connected by the Calumet River to Lake Michigan and by the Little Calumet River and Calumet-Sag Channel to the DesPlaines River. Because of these connections, it cannot be assumed fish species taken within the lake reproduce there; however, young-of-the-year of the following species were taken in the lake: Johnny darter, channel catfish, black bullhead, largemouth bass, orangespotted sunfish and gizzard shad. Gravid female and ripe male carp and fathead minnows were taken. In addition, the other species present were represented by different age groups suggesting, but not demonstrating, reproduction.

A comparison of the fishes collected in the adjacent wetlands with those from Lake Calumet shows there is nothing unique about the fish fauna of the palustrine

areas. Except for two palustrine localities where the central mudminnow was abundant (ponds south of 122nd Street), the adjacent wetlands do not support a fish fauna that is notably different from that in nearby Lake Calumet. The presence of large central mudminnow populations at the two ponds may be related to the absence of predaceous fishes, the abundance of aquatic vegetation, and their differential tolerance to winter low O_2 levels. The central mudminnow is obviously present in the Lake Calumet drainage area because that was the source for the fish fauna for the palustrine wetlands, but it must occur in low numbers and is consequently difficult to collect.

The presence of 26 fish species in Lake Calumet indicates a relatively diverse fish community. Comparisons of the Lake Calumet fish fauna with other lacustrine wetlands are difficult because of the relative sizes of the bodies of water involved. Comparisons could be made with Lake Michigan, to which Lake Calumet is connected by the Calumet River, but fish diversity is influenced by various factors including lake size and depth thereby rendering such a comparison meaningless in determining habitat quality (Barbour and Brown 1974). Thus, one cannot directly compare the 114 species of fishes recorded from all of Lake Michigan with the 26 species taken in Lake Calumet in this study. Becker (1976) surveyed the inland fishes of the Lake Michigan Drainage Basin and indicated on maps that 46 species occurred in the general vicinity of Lake Calumet, including Lake Michigan, the Grand and Little Calumet Rivers. Thus, the total number of species taken in Lake Calumet (26) is a little over half (56.5%) the number recorded from the entire area.

One species taken during this study in Lake Calumet, the orangespotted sunfish, was not listed by Becker for the Lake Michigan Drainage Basin; however, Smith (1979) indicated its presence in the Lake Calumet area on a map. Nineteen species on Becker's list were not taken in Lake Calumet during this study (Table 3). Smith (1979) assembled a set of distribution maps similar to those presented by Becker, indicating 15 species specifically from Lake Calumet. Both Becker (1976) and Smith (1979) included older published records in their distribution maps, thus the species they listed do not necessarily live in the area at the present time. Of the 15 species they listed for Lake Calumet, eight (53.3%) were pre-1908 records: lake sturgeon; bowfin; smallmouth buffalo; black buffalo; highfin carpsucker; banded killifish; and black crappie. The only species listed by Smith (1979) as a post-1950 record for Lake Calumet that we did not collect, was the Iowa darter (*Etheostoma exile*).

Meek and Hildebrand (1910) reported three species of fishes from Lake Calumet, one of which, the tadpole madtom, was not taken during this study.

Woods and Beecher (unpublished) collected eight species in Lake Calumet in 1941 and deposited their collections at the Field Museum of Natural History, Chicago. The only species they collected that was not taken in this study was a single specimen of the starhead topminnow.

Information on the fish fauna of Lake Calumet was published by Vidal and Wight (1975) in a review of the Cook County Surface Water Resources. Two fish samples were reported, one taken in 1952 and the other in 1970. The 1952 sample included northern pike and grass pickerel but these species were not present in the 1970 sample nor were they taken during this study. Collections made at Sampling Site 9 (Turning Basin Number 5) by Dennison (1978) did not contain any species that were not taken in this study.

A single specimen of the freshwater drum was taken at Sampling Site 3, in the northeastern portion of Lake Calumet. This specimen was of particular interest because the literature indicates that the species was thought to have been extirpated in that general region: "Recent records for all of northeastern Illinois are lacking, and the species has been extirpated in southern Lake Michigan" (Smith, 1979). "The freshwater drum (Fig. 109) is found in the southern two-thirds of the Basin: it is common in the lower Wolf and Fox river systems of Wisconsin; in Illinois, the drum probably is extirpated; in Indiana and lower Michigan, the species is occasionally found in the lowermost portions of tributaries to the Lake" (Becker, 1976).

Although the fish community within Lake Calumet is not unique, it is relatively good. Utilizing Karr's (1981) index to evaluate the quality of the fish fauna a score of 48 was obtained for the entire lake (Table 4). This score is within the "Good" range and is comparable to scores obtained for the Fox River (Karr 1981). Karr developed his assessment criteria for stream systems and thus the numerical boundaries for index values indicating habitat quality cannot be transferred directly to a lake situation. Two criteria utilized in his index relate directly to the difference between fluviatile and lacustrine habitats: the presence of darter species and the number of individuals of insectivorous cyprinids. One would not expect to find as many of these species present in high quality lacustrine system as in a high quality fluviatile system. Another factor to be considered is the relationship between the total number of individuals collected at a site and the sampling effort. The number of individuals collected also may be greatly influenced by large numbers of individuals of a single species, such as a school of gizzard shad in Lake Calumet. Thus, if Karr's system was designed for lacustrine wetlands, the quality would have been rated even higher. The factors contributing to this higher rating include the total number of species present (25 plus the seasonal salmon), the presence of a darter species, a good diversity of sunfish species, low numbers of green sunfish, a moderate number of individuals of insectivorous cyprinids, and the presence of top carnivores. One top carnivore, the largemouth bass, is particularly abundant in the northernmost section of Lake Calumet (site 1). The largemouth bass is an ecologically tolerant species; however, it is intolerant of excessive turbidity and siltation. Smith (1979) stated that siltation, fluctuating water levels, and a general deterioration of water quality have contributed to its decline in Illinois.

Another carnivore present in the lake and particularly abundant at site 1 was the black crappie. This species is an indicator of relatively good habitat quality because it is less tolerant of turbidity and silt than the white crappie. The latter species was much less abundant at all sites than the black crappie. The black crappie is most abundant in well-vegetated lakes and clear backwaters of rivers (Smith 1979). Another species that is indicative of clear water is the yellow perch, which also was present in site 1.

The ratio of fathead minnows to bluntnose minnows in a body of water also provides an indication of habitat quality. Larger proportions of bluntnose minnows are present in areas of reduced turbidity, whereas the fathead minnow is more common in turbid water with mud bottoms. In Lake Calumet, the bluntnose minnow was the more abundant species, whereas in the adjacent wetlands the reverse was true.

The sand shiner was relatively abundant in Lake Calumet. This species usually occurs in habitats with clear water and substrates of sand or gravel and Smith (1979) stated it "...is seldom, if ever, found in turbid streams flowing over clay or silt." Becker (1976) stated the species is often unable to adjust to increased erosion and siltation. Thus the continued existence of this species in Lake Calumet indicates the habitat has not been degraded enough to cause the extirpation of this species.

Differences in the quality of the fish fauna were noted within various portions of Lake Calumet. The highest number of species (16) was taken at three localities, the northernmost section (site 1), site 3 directly south of site 1, and site 9 at the southern end of the lake at the junction of the lake and the Calumet River. In terms of game species, higher population levels of black crappie, white crappie, largemouth bass, pumpkinseed and bluegill were present in site 1. Sand shiners, an indicator of clear water conditions also were abundant at this site. In addition, a single specimen of the spotfin shiner, a species preferring clear, weedy lakes or rivers, was taken at site 1. In referring to this species, Becker (1976) stated it "probably has been extirpated in the Illinois portion of the (Lake Michigan) Basin." The emerald shiner was more abundant at site 1 than at any other locality within the lake. Becker (1976) reported this species is an important forage fish for both predatary fish species and many bird species such as gulls, terns, mergansers, and cormorants. Because of these various factors, site 1 is considered to contain the highest quality fish community within Lake Calumet. Karr's index yielded a value of 42 for this site (Table 4).

Site 3 also contained 16 species, but the population level of game species is lower than at site 1. Two species were taken here that were not taken anywhere else in the lake, the rainbow smelt and the freshwater drum, each represented by a single individual. The Johnny darter was present at this site but absent at site 1. The reduced number of individuals of game species may be related to the shallower water at site 3 as compared to site 1. This site has a fish community second in quality only to site 1. Karr's index yielded a value of 42 for this site (Table 4).

The site within Lake Calumet that ranked third in importance as fish habitat, with a total of 16 species, was site 9 (Turning Basin 5). Except for the yellow perch, game species were either lacking or were in low numbers at this site. The Johnny darter was most abundant at site 9, as was the spottail shiner. Becker (1976) pointed out that the spottail shiner is adversely affected by pollution and siltation from industry and agriculture; thus its abundance at this site suggests water quality is good enough to allow its continued existence. Karr's index yielded a value of 44 for this site (Table 4).

Other sites within Lake Calumet varied in the quality of the fish communities present; however, there appeared to be a reduction in the number of fish species present at sites where the most extensive habitat modifications have occurred. The slips, for example, along the east side of the lake where extensive shoreline dredging has occurred (site 5) do not offer the variety of habitats available to fish species at most other sites within the lake.

At sites where soil was present along the edge of the lake (often covering the cement rubble dumped along the shore), vegetation had developed and provided additional habitat for fishes and also for invertebrates that serve as a food source

for fishes. Many sites within the lake could be greatly improved as fish habitat by covering the cement rubble with soil.

Assuming that Lake Calumet is not severely impacted in the future by pollution from adjacent industry or landfill operations, the lake should provide suitable habitat for continued existence and reproduction of fish species. Additional filling of the northern portion of Lake Calumet will have a detrimental impact upon the good fish fauna now present in that area. Construction of additional slips along the shoreline also will reduce the suitability of this area for fishes as has been demonstrated by comparing fish populations in developed and undeveloped areas.

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Table 1. Fish species recorded from the Lake Calumet area from 1876 to 1980 by various authors. Asterisks indicate species not listed in Dennison's report but found in his collections at the Field Museum of Natural History. Question marks indicate incomplete identifications, (e.g., sunfish, bullhead, crappie). CR = Calumet River, LC = Lake Calumet, LCA = Lake Calumet Area, TB = Turning Basin 5.

Scientific Name	Common Name	1 1876 CR	2 1910 LC	 CR	3 1920 LCA	4 1941 LC	5 1952 LC	5 1970 LC	6 1978 TB	7 1980 TB
Acipenser fluvescens	lake sturgeon	+								
Lepisosteus osseus	longnose gar	+								
Amia calva	bowfin		+		+					
Alosa pseudoharengus	alewife							+	+	+
Dorosoma cepedianum	gizzard shad							+	+	+
Umbra limi	central mudminnow				+					
Esox americanus vermiculatus	grass pickerel	+					+			
Esox lucius	northern pike	+			+		+			
Catostomus commersoni	white sucker	+								
Ictiobus niger	black buffalo				+					
Ictiobus bubalus	smallmouth buffalo				+					

Table 1. (continued)

Scientific Name	Common Name	1 1876 CR	2 1910 LC	CR	3 1920 LCA	4 1941 LC	5 1952 LC	5 1970 LC	6 1978 TB	7 1980 TB
Carpoides velifer	highfin carpsucker				+					
Erymyzon sucetta	lake chubsucker			+	+					
Pimephales notatus	bluntnose minnow				+	+		+	+	+
Pimephales promelas	fathead minnow							+		+
Carassius auratus	goldfish					+	+	+	+	+
Cyprinus carpio	common carp					+	+	+	+	+
Notemigonus crysoleucas	golden shiner			+	+	+				+
Notropis emiliae	pugnose minnow				+					
N. stramineus	sand shiner									+
N. heterolepis	blacknose shiner				+					
N. heterodon	blackchin shiner	+			+					
N. blennius	river shiner				+					
N. hudsonius	spottail shiner				+				+ *	+
N. spilopterus	spotfin shiner				+					
N. atherinoides	emerald shiner				+				+	+
Ictalurus melas	black bullhead			+		+	?			
Ictalurus natalis	yellow bullhead			+			?			
Noturus gyrinus	tadpole madtom		+							
Aphredoderus sayanus	pirate perch	+								
Fundulus diaphanus	banded killifish				+					

Table 1. (continued)

Scientific Name	Common Name	1 1876 CR	2 1910 LC	CR	3 1920 LCA	4 1941 LC	5 1952 LC	5 1970 LC	6 1978 TB	7 1980 TB
Fundulus dispar	starhead topminnow				+	+				
Labidesthes sicculus	brook silverside				+					
Pomoxis annularis	white crappie				+		?			
Pomoxis nigromaculatus	black crappie		+		+		?		+	+
Ambloplites rupestris	rock bass				+		+			
Lepomis cyanellus	green sunfish	+					?	+	+	+
Lepomis humilis	orangespotted sunfish								+ *	+
Lepomis megalotis	longear sunfish				+					
Lepomis macrochirus	blugill	+		+	+		+	+		+
Lepomis gibbosus	pumpkinseed				+	+			+	+
Micropterus salmoides	largemouth bass	+			+	+	+	+	+	+
Perca flavescens	yellow perch	+	+		+		+	+	+	+
Percina caprodes	logperch	+			+					
Etheostoma nigrum	johnny darter				+					
Etheostoma camurum	bluebreast darter				+					
Morone chrysops	white bass				+					

1. Nelson (1876); 2. Meek & Hildebrand (1910); 3. Forbes & Richardson (1920); 4. Woods & Beecher (1941); 5. Vidal & Wight (1975); 6. Dennison (1978); 7. Polls *et al.*, (1980).

Table 2. Number of each fish species caught (retained and released combined) at the wetlands adjacent to Lake Calumet and at each of 9 sampling sites in Lake Calumet. Frequency of occurrence for multiple samples indicated in parenthesis.

	Adjacent Wetlands (sampled 34 times)	Lake Calumet Sampling Sites (and number of times sampled)								
		1	2	3	4	5	6	7	8	9
FAMILY and Species		(4)	(2)	(3)	(1)	(2)	(1)	(1)	(1)	(2)
UMBRIDAE										
central mudminnow										
Umbra limi	410(8)									
CLUPEIDAE										
alewife										
Alosa pseudoharengus			4(2)	22(3)		14(1)			17	42(2)
gizzard shad										
Dorosoma cepedianum		405(3)	64(2)	1138(3)	428	687(2)	732	86	163	205(2)
SALMONIDAE										
chinook salmon										
Oncorhynchus tshawytscha			+	+	+	+	+	+	+	+
OSMERIDAE										
rainbow smelt										
Osmerus mordax				1(1)						
CYPRINIDAE										
goldfish										
Carassius auratus	87(7)							2		1(1)
comon carp										
Cyprinus carpio	105(6)	24(3)	2(2)	47(2)	11	55(2)	58	45		11(2)
golden shiner										
Notemigonus crysoleucas		12(3)	2(1)	3(2)			10	2		2(1)

Table 2. (continued)

FAMILY and Species	Adjacent Wetlands (sampled 34 times)	Lake Calumet Sampling Sites (and number of times sampled)								
		1 (4)	2 (2)	3 (3)	4 (1)	5 (2)	6 (1)	7 (1)	8 (1)	9 (2)
emerald shiner *Notropis atherinoides*	17(3)				1				1(1)
spottail shiner *Notropis hudsonius*								1	113(1)
spotfin shiner *Notropis spilopterus*	1(1)								
sand shiner *Notropis stramineus*	37(4)		10(2)					33	17(2)
bluntnose minnow *Pimephales notatus*	171(4)	57(2)	75(2)		90(1)	2	6	85	343(2)
fathead minnow *Pimephales promelas*	3113(19)	3(3)	46(2)	54(3)	11	19(1)	3	23	20	33(2)
CATOSTOMIDAE										
quillback *Carpiodes cyprinus*										1(1)
ICTALURIDAE										
black bullhead *Ictalurus melas*	7(2)		3(1)					21		
channel catfish *Ictalurus punctatus*					2			2		
CENTRARCHIDAE										
green sunfish *Lepomis cyanellus*	511(11)	6(3)								5(1)

Table 2. (continued)

FAMILY and Species	Adjacent Wetlands (sampled 34 times)	Lake Calumet Sampling Sites (and number of times sampled)								
		1 (4)	2 (2)	3 (3)	4 (1)	5 (2)	6 (1)	7 (1)	8 (1)	9 (2)
pumpkinseed *Lepomis gibbosus*	125(7)	101(4)	7(1)	2(1)		3(1)	4	2	1	3(1)
hybrid *L. cyanellus X L. gibbosus*	5(1)									
orangespotted sunfish *Lepomis humilis*	6(1)	39(4)	5(2)	25(1)		2(1)	2	10		3(1)
bluegill *Lepomis macrochirus*		27(3)	1(1)							
largemouth bass *Micropterus salmoides*		92(4)		5(2)		1(1)		3		
white crappie *Pomoxis annularis*		71(2)		1(1)				1		
black crappie *Pomoxis nigromaculatus*		169(4)	1(1)	6(1)				3		
PERCIDAE										
Johnny Darter *Etheostoma nigrum*			11(2)	13(2)						17(2)
yellow perch *Perca flavescens*		3(3)	99(2)	14(2)		29(1)	30		1	9(2)
SCIAENIDAE										
freshwater drum *Aplodinotus grunniens*				1(1)						

Table 3. Fish species recorded by Becker (1976) from the general area of Lake Calumet not taken during 1981-82 fish survey.

Scientific Name	Common Name
Amia calva	bowfin
Esox americanus vermiculatus	grass pickerel
Esox lucius	northern pike
Notropis blennius	river shiner
Notropis emiliae	pugnose minnow
Notropis heterodon	blackchin shiner
Notropis heterolepis	blacknose shiner
Carpiodes velifer	highfin carpsucker
Erimyzon oblongus	creek chubsucker
Ictiobus bubalus	smallmouth buffalo
Ictiobus cyprinellus	bigmouth buffalo
Noturus gyrinus	tadpole madtom
Fundulus diaphanus	banded killifish
Fundulus dispar	starhead topminnow
Labidesthes sicculus	brook silverside
Ambloplites rupestris	rock bass
Lepomis megalotis	longear sunfish
Etheostoma exile	Iowa darter
Percina caprodes	logperch

Table 4. EVALUATION OF FISH COMMUNITIES AT WETLAND UNITS. (Quality grades used are minus, 1 point; zero, 3 points; and plus, 5 points. Numbers in parentheses are numbers of species or individuals.)

			Number of			
Sampling Site	Total Species	Total Individuals	Darter Species	Sunfish Species	Sucker Species	Intolerant Species
1	+ (16)	+ (1178)	– (0)	+ (3)	– (0)	– (0)
2	+ (13)	0(302)	0(1)	+ (3)	– (0)	– (0)
3	+ (16)	+ (1417)	0(1)	+ (2)	– (0)	– (0)
4	– (4)	0(452)	– (0)	– (0)	– (0)	– (0)
5	0(9)	+ (900)	– (0)	+ (2)	– (0)	– (0)
6	0(9)	+ (842)	– (0)	+ (2)	– (0)	– (0)
7	+ (13)	0(206)	– (0)	+ (2)	– (0)	– (0)
8	0(8)	0(339)	– (0)	0(1)	– (0)	– (0)
9	+ (16)	+ (804)	0(1)	+ (2)	0(1)	– (0)
Entire Lake	+ (25)	+ (6440)	0(1)	+ (3)	0(1)	– (0)

Sampling Site	Proportion of					
	Omnivores	Insectivorous Cyprinids	Green Sunfish	Top Carnivores	Hybrids	Diseased etc.
1	– (615)	+ (55)	0(6)	+ (335)	+ (0)	+ (0)
2	– (178)	– (0)	+ (0)	+ (100)	+ (0)	+ (0)
3	– (1339)	9(10)	+ (0)	0(26)	+ (0)	+ (0)
4	– (450)	– (0)	+ (0)	– (0)	+ (0)	+ (0)
5	– (865)	– (0)	+ (0)	0(30)	+ (0)	+ (0)
6	– (805)	– (1)	+ (0)	0(30)	+ (0)	+ (0)
7	– (185)	– (0)	+ (0)	0(7)	+ (0)	+ (0)
8	– (285)	+ (34)	+ (0)	0(19)	+ (0)	+ (0)
9	– (638)	+ (131)	0(5)	0(9)	+ (0)	+ (0)
Entire Lake	– (5360)	+ (231)	+ (11)	+ (556)	+ (0)	+ (0)

Sampling Site	Quality Index	Class for Streams
1	42	fair
2	40	fair
3	42	fair
4	26	poor
5	32	poor
6	31	poor
7	36	fair-poor
8	36	fair-poor
9	44	fair
Entire Lake	48	good

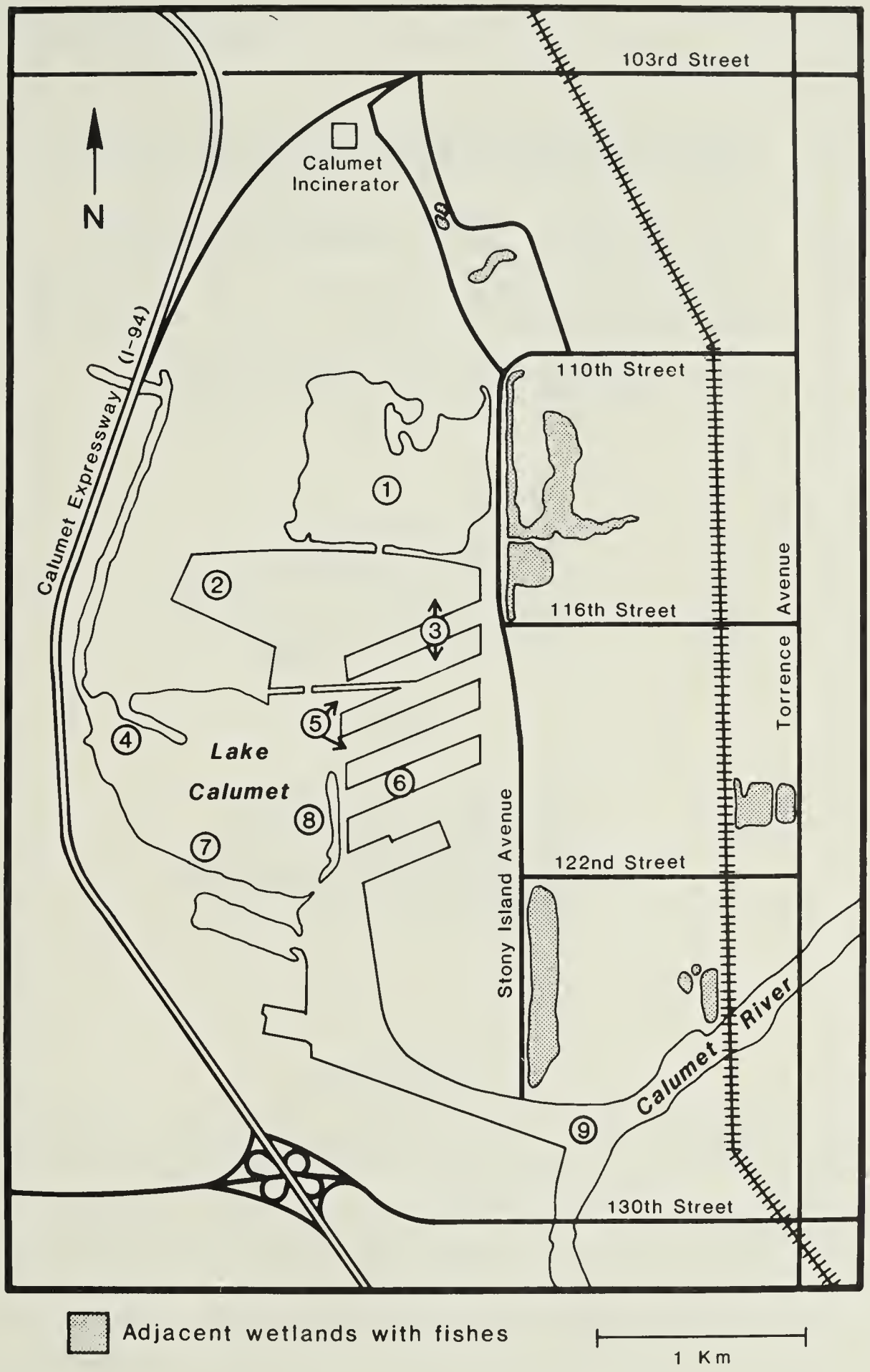

Figure 1. Map of Lake Calumet and its adjacent wetlands that contain fishes showing sampling sites 1-9.

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MACROINVERTEBRATES AND FISHES OF TROUT PARK NATURE PRESERVE, ELGIN, ILLINOIS

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ABSTRACT

The composition and relative abundance of macroinvertebrate and fish species of Trout Park Nature Preserve, Elgin, Illinois, are reported. The species list reflects an intensive, 1-year survey resulting in 48 species of invertebrates. *Gammarus pseudolimnaeus*, *Asellus intermedius*, and several species of caddisflies were the dominant species. The mottled sculpin was the only fish species collected in the park. Erosion is the major factor accounting for the moderately low number of species inhabiting Trout Park. The species list resulting from this survey can be used as a baseline upon which future investigations can be compared.

INTRODUCTION

The Trout Park Nature Preserve (Elgin Botanical Gardens) is a small 10.5-ha area located on the east bluff of the Fox River in the north end of Elgin. An unususal natural area (Evers and Page, 1977), it is a glacial remnant of the morainic hills of northern Illinois (Paulson, 1972), and known for its diverse floral composition (Illinois Nature Preserves Commission, 1977; Evers and Page, 1977). Trout Park is also known for its diverse caddisfly (Trichoptera) fauna (Ross, 1944) which inhabits the five brooks and numerous springs and seeps.

Other aquatic insects have occasionally been identified in Trout Park, usually in conjunction with reports on particular insect orders within Illinois, e.g., mayflies

(Burks, 1953) and stoneflies (Frison, 1942). Although Unzicker and Sanderson (1974) did a one day survey of the aquatic insects, an intensive survey of the aquatic fauna has not been conducted. The composition and relative abundance of macroinvertebrate and fish species reported herein are based on an intensive, year-long study conducted in the park and should provide a basis for future comparisons to determine the park's status and to examine the macroinvertebrate community structure in the park.

STUDY SITES AND METHODS

Details regarding the location of the Trout Park Nature Preserve and the characteristics of the site have been previously described (Vinikour and Anderson, 1981). Macroinvertebrates were collected by kick nets; surber nets; and hand-picking of rocks, logs, leaf packs, and debris from the streambed. Sampling was conducted monthly from September 1979 through August 1980. The entire length of each major brook and portions of most rivulets and seeps were surveyed on each sampling date. The relative abundance for each species was determined both in terms of specific area collected and park-wide distribution.

RESULTS AND DISCUSSION

During the survey, 48 taxa of macroinvertebrates and 3 species of fish were identified; only 11 invertebrate species were numerically abundant (Table 1).

Although many small streams typically have a naturally low diversity (Hilsenhoff, 1977), the number of macroinvertebrate species of Trout Park is somewhat lower than that found in other spring-fed headwater streams. For example, Mackay (1969) identified at least 120 insect species in her study of a small Quebec stream, and Minckley (1963) identified about 113 invertebrate species (excluding annelids) in his study of Doe Run, Kentucky. Both the shorter length of Trout Park brooks relative to those in the studies mentioned above and perturbations (mainly erosion) to the brooks are causative factors in the observed lower species composition.

The following discussion will provide information on the important species of Trout Park, including information on capture location, importance to the biotic community, and historical comparisons. Species will not be discussed or only briefly mentioned if (1) they are commonly encountered inhabitants of small streams and aspects of their life history are well documented, or (2) they could only be identified to genus and ubiquitously occur in streams of all sizes (e.g., chironomids).

Ephemeroptera. Only one species of mayfly, *Baetis tricaudatus* (= *vagans*), was distributed throughout the park. This species is the most widespread *Baetis* species in North America (Morihara and McCafferty, 1979) and was the only mayfly species reported in Trout Park by Burks (1953). *Potamanthus myops* and *Caenis hilaris* (?) were only collected along the outlet channel of the main brook that leads into the Fox River. The nymphal habitat of both species (see Edmunds et al., 1976) and their rare occurrence in Trout Park strongly imply that they normally inhabit the Fox River. Individuals of these species may rarely venture into the lower reach of Trout Park from the adjacent backwater area of the Fox River.

TABLE 1. Macroinvertebrate and Fish Species of Trout Park Nature Preserve, 1979-1980

Taxon		Relative Abundance[1]
Turbellaria		
Planariidae:	Dugesia dorotocephala	Abundant
Amphipoda		
Gammaridae:	Gammarus pseudolimnaeus	Abundant
Isopoda		
Asellidae:	Asellus intermedius	Abundant
Gastropoda		
Amnicolidae:	Amnicola	Common
Physidae:	Physa gyrina	Common
Planorbidae:	Gyraulus parvus	Rare
Coleoptera		
Dryopidae:	Helichus fastigiatus	Common
Dytiscidae:	Agabus	Common
	Copelatus glyphicus	Rare
Elmidae:	Optioservus fastiditus	Rare
Eubriidae:	Ectopria leechi (?)	Rare
Hydrophilidae:	Anacaena limbata	Common
	Cymbiodyta	Common
	Hydrobius tumidus (?)	Common
Ephemeroptera		
Baetidae:	Baetis tricaudatus	Abundant
Caenidae:	Caenis hilaris (?)	Rare
Potamanthidae:	Potamanthus myops	Rare
Hemiptera		
Gerridae:	Gerris remigis	Common
Veliidae:	Microvelia americana	Common
Megaloptera		
Sialidae:	Sialis	Rare
Plecoptera		
Nemouridae:	Amphinemura delosa	Common
	Nemoura trispinosa	Common
Perlodidae:	Clioperla clio	Abundant
Collembola		
Isotomidae:	Isostomus palustris	Common
Diptera		
Chironomidae:	Corynoneura	Rare
	Cricotopus	Common
	Eukiefferiella	Abundant
	Orthocladius	Rare
	Parametriocnemus	Rare
	Rheocricoptopus	Rare
	Polypedilum	Rare
	Microspectra	Rare
Dixidae:	Dixa	Common
Empididae		Common
Simuliidae:	Simulium venustum	Abundant
Stratiomuidae:	Euparyphus	Common
Tipulidae:	Dicranota	Common
	Limonia	Rare
	Tipula abdominalis	Abundant
Trichoptera		
Glossosomatidae:	Glossosoma intermedium	Abundant
Hydropsychidae:	Diplectrona modesta	Abundant
	Symphitopsyche bronta	Rare
	Symphitopsyche slossonae	Rare
Hydroptilidae:	Hydroptila consimilis	Common
Lepidostanatidae:	Lepidostoma liba	Common
Limnephilidae:	Hesperophylax designatus	Common
	Neophylax concinnus	Abundant
Philopotamidae:	Wormaldia moesta	Rare
Pisces		
Cyprinidae:	Semotilus atromaculatus	Rare
Gasterosteidae:	Culaea inconstans	Rare
Cottidae:	Cottus bairdi	Rare

[1] Abundant - found throughout the park, usually in large numbers; common - found throughout the park in low numbers or found in localized areas in large numbers; rare - restricted distribution and density in the park.

Unzicker and Sanderson (1974) collected a fairly diverse assemblage of mayflies in their brief survey of the park: *Baetis tricaudatus, Siphloplecton, Ephemerella, Pseudocloeon, Ephemera, Epeorus, Cloeon, Paraleptophlebia moerens,* and *P. praepedita.* Some of these species may have inhabited the main brook due to altered water qualilty and substrate conditions in the late 1960s through 1977 when the storm sewer was routed into the brook.

Plecoptera. The three species of stoneflies—*Amphinemura delosa, Nemoura trispinsoa,* and *Clioperla (= Isoperla) clio*—were common to abundant throughout

much of the park. *Clioperla* is the largest of the species and was commonly encountered within leaf litter packs and upon wood debris. *Clioperla* was the only stonefly species found in the lower reach of the main brook (the reach that receives rerouted storm-sewer drainage), although it occurred only in low numbers.

Initially, Frison (1935) did not report any stonefly species from Trout Park, but he subsequently reported the occurrence of *Nemoura trispinsoa* and *Leuctra tenius* (Frison, 1942). He only collected adults of *L. tenius* and—considering that this species of *Leuctra* is an inhabitant of large, warmwater rivers and streams (Harper and Hynes, 1971)—it is probable that the nymphs inhabit the adjacent Fox River and not Trout Park itself. Unzicker and Sanderson (1974) reported *Acroneuria arida*, *Paracapnia*, and *Alloperla* from Trout Park. As with the mayfly species reported by Unzicker and Sanderson, one can only conjecture that storm-sewer impacts accounted for the above-mentioned species being present in 1974 but absent in either the previous (Frison, 1942) or current survey.

Trichoptera. Nine species of caddisflies were collected (Table 1). Three of these species—*Glossosoma intermedium*, *Hesperophylax designatus*, and *Wormaldia moesta*—are not known from other Illinois locales, whereas two of the species—*Diplectrona modesta* and *Lepidostoma liba*—have only been found locally elsewhere in Illinois (Ross, 1944). *Hydroptila consimilis* primarily occurred on *Cladophora* located in the lower portions of the main brook, whereas *Glossosoma* occured abundantly on cobble in portions of the brooks that had open canopies. The other commonly to abundantly occurring species primarily inhabited wood debris, although *Diplectrona* also inhabited leaf packs and *Neophylax concinnus* also occurred on *Cladophora.* Conditions in the main brook have improved since rerouting of the storm sewer (i.e., all nine species were found in the main brook in the current study compared to no caddisflies observed by Unzicker and Sanderson in 1974). However, the park as a whole is continuing to deteriorate, especially the smaller brooks. Several of these brooks have sediments predominated by fine silts and marl. In those brooks, caddisflies are confined to selected reaches where cobble or wood debris still occur. Elimination of several of the less common species and a decrease in the more common ones are foreseeable if off-trail hiking and unlimited access from the bluff top, which create erosive conditions, are allowed to persist.

Amphipoda and Isopoda. Gammarus pseudolimnaeus and *Asellus intermedius* were the only amphipod and isopod species encountered in this survey. *Gammarus* was more abundant than *Asellus*, and occurred throughout most of the park, including the small rivulets and seepage areas. Watercress beds particularly harbored high densities of *Gammarus*. Watercress beds increase streambed area and reduce stream velocities, thereby enhancing sedimentation and aiding seston and leaf litter retention. This expedites detrital processing, and the watercress itself becomes a major source of autochthonous detrital matter (Anderson and Sedell, 1979), which probably accounts for the large population densities of *Gammarus* in watercress.

Asellus was more prominant in the lower reaches of the brooks where leaf packs occurred. Being tolerant of organically enriched areas (Ellis, 1961), *Asellus* was the most abundant species within the outlet area of the main brook. Storm-sewer discharge is similar in many respects to sewage effluent and creates a situation in the lower reach of the main brook where only the species tolerant to organic pollution can thrive.

Although only a single species each of amphipod and isopod occur in Trout Park, the low species richness is compensated for by the fact that both species have high biomass, mixed age distribution, and year-round presence (Anderson and Sedell, 1979). Their abundance in Trout Park, coupled with being principally detritivores, make *Gammarus* and *Assellus* the primary link in the energy transfer between the terrestrial and aquatic systems in Trout Park.

Coleoptera. Eight beetle species were collected (Table 1), predominantly on wood debris. All these species belong to genera normally encountered within spring-brook environments. In the park, logs remain relatively unaltered, irregardless of changes to the mineral substrates occurring due to erosion. As erosion has led to tree fall within the park, brook habitat capable of supporting the beetle species has increased over time. Unzicker and Sanderson (1974) reported four of the species *(Agabus*, *Optioservus*, *Helichus*, and *Cymbiodyta)* in their survey, which suggests that the beetle species composition has remained relatively unchanged within recent years.

It is uncertain as to whether the *Ectopria* species is *leechi* or the more commonly known *nervosa*. *Ectopria leechi* is a recently described species (Brigham, 1981) with a distribution and larval habitat that emcompasses the locale and habitat conditions of Trout Park. Unfortunately, only two larvae were collected, ruling out a specific determination at this time.

Diptera. Fifteen dipteran species representing six families were collected. Chironomids accounted for eight of the species. Midge density was low within the brooks, a situation that may indicate some improvement in quality of the main brook since the storm sewer has been rerouted. Unzicker and Sanderson (1974) reported chironomids to be abundant in the main brook, probably due to nutrient enrichment and sedimentation caused by the storm sewer at that time.

In the current survey, only areas of fine silt deposits (usually associated with logjams) harbored high densities of midges. However, midges, in particular *Eukiefferiella*, were commonly encountered within pupal cases of the caddisflies *Glossosoma intermedium* and *Hesperophylax designatus* (Vinikour and Anderson, 1981). Considering that these caddisflies are numerous within the park, the abundance of *Eukiefferiella* is also potentially high.

Tipula abdominalis was the largest invertebrate found in Trout Park; it was abundant in leaf litter packs and common within areas of accumulated wood debris. Its size and abundance makes it important in the initial breakdown of leaf litter and, therefore, nutrient cycling within the brooks. *Tipula* also loosens the material within leaf packs, allowing other species to penetrate the packs (Cummins, personal communication—cited in Anderson and Sedell, 1979).

Dixa (Dixidae) was confined to the shallow (5 cm) rivulets located in the upper reaches of the brooks.

Simulium venustum, a well-known pest species (Westwood and Brust, 1981) and one of the commonest blackfly species in the United States (Stone, 1964), was abundant in Trout Park, expecially within the lower reaches of the main brook. Temperature requirements for development (see Mokry, 1976) and food resource limitations may account for its low density within the upper reach of the main brook.

As with *Eukiefferiella*, larvae of an unidentified species of Empididae were commonly encountered within *Glossosoma* and *Hesperophylax* pupal cases. This can be considered an ectoparasitic association in that the empidids feed upon the

pupal caddisflies. Vinikour and Anderson (1981) postulated that the association may aid in the regulation of caddisfly populations in streams where vertebrate and large invertebrate predators are scarce.

Turbellaria. The planarian *Dugesia dorotocephala* was abundant especially in the main brook under the I-90 overpass. This species is a common inhabitant of cool, unpolluted springs, creeks, and spring-fed marshes and lakes (Kenk, 1944). The species was abundant in the same area in 1976 when the storm sewer was still routed into the main brook and while I-90 snowmelt drainage was discharging directly on them (Vinikour, unpublished data). This indicates that *D. dorotocephala* may be more tolerant of polluted conditions than previously reported and more limited by thermal requirements.

Gastropoda. The snail species common to Trout Park, *Physa gyrina* and *Amincola*, are typical inhabitants of small streams. Both species predominantly inhabited wood debris. The snails' feeding activities (grazing on periphyton) aid in detrital particle size reduction by removing the superficial layers of wood. Snails therefore contribute to the initial degradation of coarse particulate organic matter (Anderson et al., 1978; Anderson and Sedell, 1979).

Pisces. Trout Park receieved its name because an early owner of the land stocked trout in the 1850s. Trout probably have not occurred in the brooks for over a hundred years, and 1930 newspaper articles on the park make no mention of trout (see Evers and Page, 1977). Evers and Page (1977) did list the mottled sculpin and brook stickleback as unusual vertebrates occurring in the spring-fed rivulets of Trout Park, which implies that these species are common in Trout Park. It is doubtful, however, that the species have been common to the park since perturbation by I-90 construction and storm-sewer routing. Currently, these species and the creek chub are rare inhabitants of the park.

Only the mottled sculpin occurs within the park proper, primarily confined within a small area of the main brook (Vinikour and Anderson, 1980) although two individuals have recently been observed in the upper reach of the main brook. This indicates that logjams and other impediments are passable, at least during high flows, and that a large stretch of the main brook may eventually be populated by the sculpin. The occurrence and preservation of the mottled sculpin in Trout Park is important in that much of its habitat within northern Illinois is being rapidly destroyed by stream alterations (Smith, 1979).

Only a few specimens of creek chub were collected, all within the lower reach of the main brook near the outlet to the Fox River. Apparently the creek chub does not populate Trout Park and its occurrence only indicates forays by individuals a short distance into the brook from the Fox River.

Several brook sticklebacks were also collected within the lower outlet reach of the main brook. A stickleback population also occurs within the drainage area of two of the smaller brooks in a cattail-infested area with silt substrates, reduced flows, and shallow (<0.3m) water. Stickleback inhabitation of the drainage area probably centers around the breeding season, whereas they tend to overwinter in deeper water (Wootton, 1976), preferring temperatures of 15 to 19°C (MacLean and Gee, 1971).

CONCLUSION

Although Trout Park is currently degraded in comparison to conditions that existed prior to I-90 construction and storm-sewer routing, most invertebrates that inhabit the brooks are normally encountered in good-to high-quality streams (see Hilsenhoff, 1977). This reflects the presence of unaltered reaches that still exist in the brooks, abundant wood debris that harbors many of the species, and the fact that erosion rather than water quality degradation is the primary impact to the park.

It is hoped that mitigative measures will be implemented in an effort to control the erosive conditions that are accelerated by off-trail hikers. Even though the faunistic composition of the Trout Park brooks is restricted due to past and ongoing perturbations, the brooks still contain an unusual aquatic community including several rare species of caddisflies. The current survey can serve as a reference to which future conditions may be compared, allowing the effectiveness of mitigative measures to be measured.

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REDUCED TILLAGE FOR MILLET ESTABLISHMENT IN WHEAT STUBBLE

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ABSTRACT

A study was conducted at Carbondale in southern Illinois on an imperfectly drained Stoy silt loam soil (fine-silty, mixed, mesic Aquic Hapludalfs) to determine the feasibility of establishing and producing forage millet in wheat stubble and to evaluate soil moisture regimes. Millet [*Pennisetum americanum* (L) Leche] was planted in wheat stubble in late June using three tillage systems (conventional, minimum and no-till) and three seeding implements (Allis Chalmers No-Till Planter, Brillion Seeder and the International Grain Drill). Adequate and well distributed rainfall was essential for good millet establishment and production. Generally, no-till and minimum tillage systems had higher soil moisture levels than conventional tillage. The no-till planter was the only acceptable seeding implement for minimum and no-till systems under limited surface soil moisture conditions. Under conventional tillage, the grain drill was the most suitable planter. Millet can be successfully established in wheat stubble if the proper seeding implement is used.

INTRODUCTION

There is a need for proper conservation measures to reduce soil erosion and water runoff. Farmers are interested in cultural practices that give the greatest profits and at the same time provide adequate soil and water conservation. The use of reduced tillage systems increases crop residues left on the soil surface which aid soil water recharge and help control water and wind erosion (1).

In the past, conventional tillage was considered necessary. However, the concepts regarding tillage requirements for crop production are changing. With the development of effective non-residual herbicides, the need for conventional tillage is being questioned. It is now possible to spray weeds and have a rapid kill, leaving the seedbed free from any residual herbicide activity.

Farmers are using reduced tillage practices to lessen labor and machinery

costs and to increase yields (3, 5, 8). Fewer trips over the field can result in reduced costs and less damage to the soil structure by compaction.

Reduced tillage systems have been studied extensively for row crops such as corn (*Zea mays* L.) and soybeans (*Glycine max* L.) (2, 4). Soybeans have been seeded with no-till planters in standing wheat (*Triticum aestivum* L.) stubble immediately after harvest to take advantage of firm moist soil (4). Thus, no-till has greatly improved the possibility of double cropping by conserving soil moisture and time. No-till double cropping success is increased by (a) an excellent stand of well-fertilized small grain that controls weeds until it is harvested; (b) early removal of the small grain to increase the chance for maturity and increased yield of the second crop; (c) sufficient moisture; and (d) adequate fertility for the second crop.

No-till seeding of forage legumes and grasses into permanent pasture sod without complete seedbed preparation has been successful (6, 7). Stands of red clover (*Trifolium pratense* L.) and tall fescue (*Festuca arundinacea* Schreb.) have been established in wheat stubble with minimum tillage and no-till practices (5). Forages sown in the late summer in wheat stubble enhance winter cover, thereby providing better protection from soil erosion and water runoff.

The objectives of this study were (a) to determine the feasibility of establishing and producing millet [*Pennisetum americanum* (L) Leche] in wheat stubble immediately after harvest in the latter part of June; (b) to evaluate different seeding implements and tillage systems; and (c) to assess the effects of selected tillage practices on soil moisture regimes.

MATERIALS AND METHODS

The study was conducted at the Agronomy Research Center at Carbondale in southern Illinois on an imperfectly drained Stoy silt loam soil (fine-silty, mixed, mesic Aquic Hapludalfs) during 1979 and 1980. Soil tests indicated that the pH, phosphorus and potassium levels were high, and thus lime and fertilizer materials were not applied to the experimental sites. A broadcast application of 112 kg/ha/N of ammonium nitrate was made each year with a side dressing of 60 kg/ha/N of ammonium nitrate after the first harvest of millet. Wheat was harvested in late June each year of the study and Paraquat (1,1'-dimethyl-4,4'bipyridinium dichloride) was sprayed on the wheat stubble at the rate of 0.6 kg/ha active ingredient for weed desiccation. The wheat straw residue was about 3.4 metric tons/ha.

The forage millet was seeded at the rate of 20 kg/ha in late June using three tillage systems and three different seeding implements. The tillage systems consisted of the following: (a) conventional tillage — the land was moldboard plowed to turn under the residue from the wheat crop, and subsequently disked and harrowed; (b) minimum tillage — the preparation of the seedbed consisted of two diskings, (c) no-till-no actual tillage was performed, but soil was disturbed as required in the planting operation. The seeding implements used were the Allis Chalmers No-Till Planter, Brillion Seeder, and the International Harvester Grain Drill for each of the three tillage methods. All of the treatments were replicated four times in a split plot experimental design. The sub-plots were 4 × 8 meters.

The millet stands were evaluated visually and rated from 0 to 100 percent. A

rating of 100 percent indicates that there were at least 30 millet plants per square meter and that they were evenly distributed.

The millet was harvested for forage with a portable sickle bar mower. Total herbage fresh weight from each treatment was recorded and sub-samples were taken and oven dried for 24 hours at 90°C to determine the moisture content of the herbage and dry matter yields.

Soil moisture regimes were ascertained by taking soil samples periodically during the growing season in all tillage treatments for comparison. The soil samples were obtained in the plow layer to a depth of 25 cm and placed in aluminum cans immediately after sampling. In the laboratory the samples were weighed, oven dried at a temperature of 105°C for 24 hours, and reweighed to determine soil moisture percentages.

RESULTS AND DISCUSSION

Rainfall before and after planting on June 28, 1979, was adequate for millet germination and establishment (Table 1). The soil moisture regime for the 1979 millet growing season is given in Figure 1. Soil moisture percentages by weight varied 1-4% more in the minimum tillage treatments than for conventional tillage. Probably the two major factors influencing these differences were evapotranspiration rates and soil-water recharge. Average soil moisture was near permanent wilting 8 days after planting for the 25 cm depth. Germination and emergence of the young seedlings were attributed to light showers that occurred during this period. The 5.2 cm rain on July 9, 1979, (Table 1) was sufficient to recharge the plow layer and establish millet successfuly. The total rainfall for July (13.1 cm) was only 1 cm less than for August (Table 2). However, the level of soil moisture for August was much higher than for July. This difference may be attributed mainly to rainfall distribution. There were four rainfall events in August with more than 2 cm/rain, whereas, July had only 2 rainfall events with more than 2 cm/rain. With smaller, more frequent rainfalls, a higher percentage of the rainfall was entrapped on the surfaces of the plants. Therefore, the relative percentage of water loss by evaporation was greater.

In 1980, the millet was planted on July 7. Soil moisture was sufficient for germination, emergence and stand establishment when seeds were placed at the proper depth (Table 1). Most of the seeds planted at a shallow depth germinated but then desiccated due to lack of rain for two weeks following planting. Soil moisture was highest for the no-till treatments and lowest for conventional tillage (Figure 2). The differences in soil moisture for the tillage treatments were similar to the 1979 millet growing season. The rainfall for the month of August, 1980 was extremely low and thus the soil moisture was near the permanent wilting point for most of the month. The growth of millet during this period was severely restricted and yields were low.

The two growing seasons varied in the amount and distribution of rainfall (Table 1). During the first growing season, there was ample rainfall and good distribution permitting good millet establishment and production. In contrast, the second growing season had lower rainfall and poor distribution which resulted in lower yields.

Stands were evaluated immediately after the first harvest by counting the

number of millet plants per meter square and their distribution. Acceptable stand ratings were obtained the first year of the study within the minimum and conventional tillage system with the International Grain Drill and the Brillion Seeder (Table 3). Ample late summer rainfall in 1979 resulted in excellent growth and production. Dry matter yields were comparable for minimum or conventional tillage with both the International Grain Drill and the Brillion Seeder.

The second year of the study, the no-till system and the Allis Chalmers No-Till Planter were also evaluated in addition to the other treatments. Very good stands were obtained in conventional tillage with the Allis Chalmers No-Till Planter and the International Grain Drill. However, the use of the Brillion Seeder resulted in poor stand ratings and low yields for all tillage systems. Only the Allis Chalmers No-Till Planter had an acceptable stand rating in the minimum tillage and no-till systems (Figure 3). Low rainfall reduced the amount of soil moisture the second year of the study. The grain drill used on conventional tillage resulted in the highest total dry matter yield of millet; however, the use of the Allis Chalmers No-Till Planter also gave good production. Very low yields in conventional tillage occurred with the Brillion Seeder the second year. As the Brillion Seeder plants at a shallow depth, the millet seedlings desiccated after germination and died due to lack of soil moisture. Although the Brillion Seeder is a valuable implement for establishing forages in the spring or fall when surface soil moisture conditions are more favorable, it may not be suitable for planting in late June after wheat harvest as the surface soil moisture is often inadequate as was the case in 1980.

Acceptable stands and yields of millet occurred only in minimum tillage and no-till systems when the Allis Chalmers No-Till Planter was used. The International Grain Drill was an acceptable seeding implement for planting millet following wheat in the conventional tillage system.

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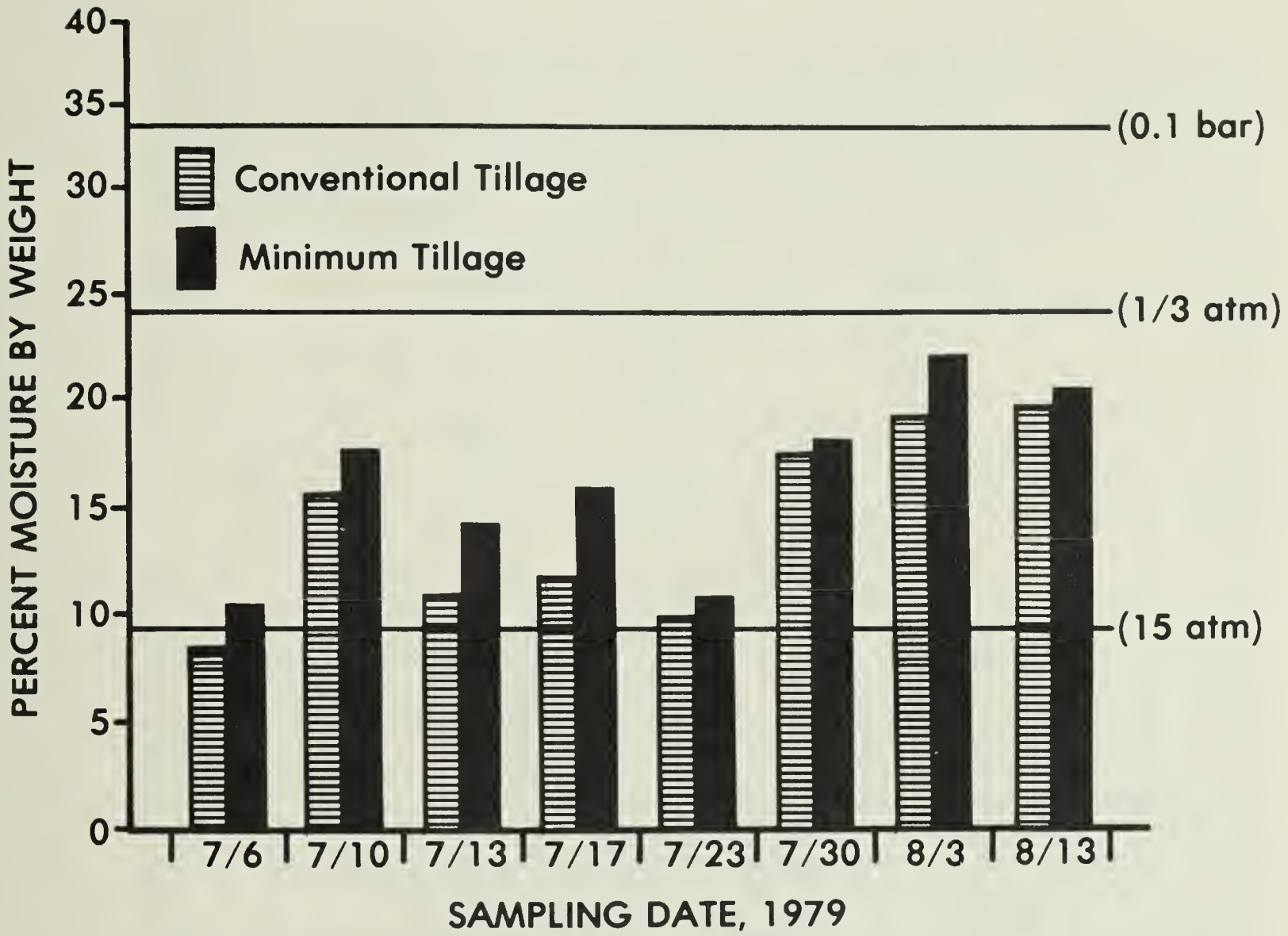

Figure 1. Soil moisture percentages by weight and tensions during the 1979 growing season for conventional and minimum tillage systems.

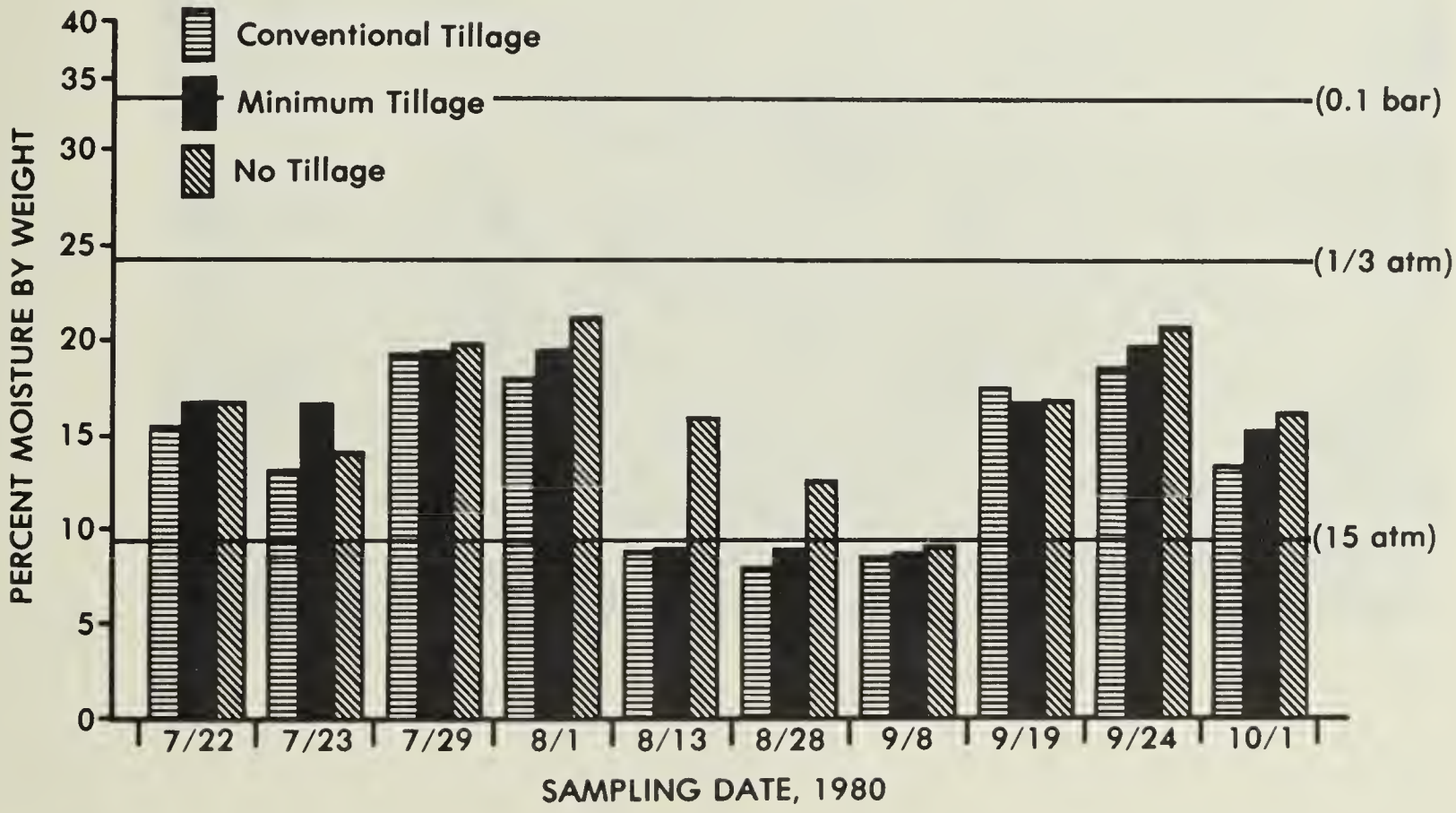

Figure 2. Soil moisture percentages by weight and tensions during the 1980 growing season for conventional, minimum tillage and no-tillage systems.

Figure 3. Millet establishment in wheat stubble with a no-till planter.

Table 1. Rainfall from June-Sept. 1979 and 1980 at Carbondale, IL.

1979		Rainfall	1980		Rainfall
		-cm-			-cm-
June	3	0.3	June	3	0.6
	7	2.5		7	0.1
	8	1.4		8	0.3
	23	3.9		23	3.4
	24	0.7		24	2.5
		8.8		29	7.9
					14.8
July	2	0.5	July	1	1.5
	4	0.2		7	3.4
	6	0.3		22	1.3
	7	0.2		28	3.6
	9	5.2			9.8
	10	0.3			
	12	0.1	Aug.	2	0.3
	16	1.1		15	1.9
	24	0.6		19	0.6
	25	0.2		28	0.2
	26	0.6			3.0
	27	0.6			
	28	2.9	Sept.	2	0.1
	31	0.3		4	0.1
		13.1		6	1.4
				17	4.6
Aug.	1	2.3		22	2.5
	2	0.5			8.7
	10	0.7			
	11	2.3			
	15	2.4			
	24	0.8			
	28	0.1			
	29	1.4			
	30	3.6			
		14.1			
Sept.	21	2.7			
	22	0.8			
		3.5			

Table 2. Monthly mean maximum and minimum temperature and rainfall from June - Sept. 1979 and 1980 at Carbondale, IL.

	1979 Temperature			1980 Temperature		
Month	Max	Min	Rainfall	Max	Min	Rainfall
	----°C----		cm	----°C----		cm
June	30.1	15.1	8.8	31.4	15.7	14.8
July	30.8	19.2	13.1	35.1	21.1	9.8
Aug.	30.6	26.1	14.1	34.9	20.9	3.0
Sept.	27.5	11.6	3.5	30.5	16.6	8.7

Table 3. Effects of tillage systems and seeding implements on stand ratings and dry matter yields of millet during 1979 (Planted June 28).

Seeding Implements	Stand Ratings†	Dry Matter Yields
	%	metric tons/ha
	Minimum Tillage	
Grain Drill	86 a*	16.8 a
Brillion Seeder	80 a	13.7 a
	Conventional Tillage	
Grain Drill	86 a	16.0 a
Brillion Seeder	85 a	14.0 a

†Stand ratings were evaluated visually and rated from 0 to 100% based on 30 millet plants per meter square and their distribution.

*Means in the same column with the same letter are not significantly different at the 5% probability level.

Table 4. Effects of tillage systems and seeding implements on stand ratings and dry matter yields of millet during 1980 (Planted July 7).

Seeding Implements	Stand Ratings†	Dry Matter Yields
	%	metric tons/ha
	No-Till	
A.C. No-Till	66 bc*	6.9 b
Grain Drill	10 e	0.9 e
Brillion Seeder	8 e	0.9 e
	Minimum Tillage	
A.C. No-Till	85 ab	6.6 b
Grain Drill	51 cd	4.6 c
Brillion Seeder	43 d	3.5 cd
	Conventional Tillage	
A.C. No-Till	94 a	7.1 b
Grain Drill	98 a	8.7 a
Brillion Seeder	33 d	2.4 d

†Stand ratings were evaluated visually and rated from 0 to 100% based on 30 millet plants per meter square and their distribution.

*Means in the same column with the same letter are not significantly different at the 5% probability level.

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PRODUCTIVITY OF GIANT CANADA GEESE IN WEST-CENTRAL ILLINOIS[1]

Key words: *(Branta canadensis maxima)*, Canada geese, Illinois, predation, productivity.)

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Branta canadensis maxima, the largest race of Canada geese, was thought extinct over 50 years ago, although there was some question as to the existence of a distinct subspecies at that time (Phillips and Lincoln 1930, McAtee 1944, Delacour 1954). Since Hanson's (1965) documentation of the race, efforts to establish and expand local populations have been widespread, with notable successes on public lands in the north-central United States (Nelson 1963, Dill and Lee 1970). However, published information on the productivity of re-established unconfined flocks has been sparse (Hunt and Jahn 1966, Szymczak 1975, Kaminski et al. 1979, Nigus and Dinsmore 1980).

In 1967, the Illinois Department of Conservation (IDOC), through the dedicated efforts of former Chief Waterfowl Biologist George C. Arthur, established a captive flock of *maxima* on private reclaimed surface-mined lands in west-central Illinois; 64 geese were released from holding pens in Fulton and Knox counties in early spring 1969. Juvenile geese used in the original stocking, which

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Hanson (1965) verified as *maxima*, were raised at the Des Plaines game farm near Wilmington, Illinois. Three hundred forty-five additional geese, purchased from private breeders, were released in Fulton, Knox, and Henry counties between 1969 and 1971. All townships designated as production areas have been closed to Canada goose hunting since 1969. Fall population estimates by the IDOC prior to 1979 were 500 in 1972, 700 in 1973, 950 in 1974, 1,200 in 1975, 1,500 in 1976, 2,000 in 1977, and 3,000-4,000 in 1978. These were based on results of banding operations, estimates of pioneering groups, and spring aerial surveys conducted some years.

The purpose of this study was to determine productivity of the established breeding population and to establish baseline data with management implications for evaluating population changes. During 1979 and 1980, size and distribution of the population, nest site characteristics, and reproductive success were evaluated. The findings presented are taken from a thesis submitted as partial fulfillment of the requirements for the M.A. Degree, Department of Zoology, Southern Illinois University at Carbondale.

STUDY AREA

The giant Canada goose production area is approximately 28,365 ha of surface-mined land in west-central Illinois (Illinois Dep. Mines and Minerals 1978, K. Russell, unpubl. data). This 4-county area includes 17,783 ha in Fulton, 8,362 ha in Knox, 1,137 ha in Peoria, and 1, 083 ha in Henry (Fig. 1). Water areas were largely permanent lakes and included approximately 2,244 ha (Haynes and Klimstra 1975, and unpubl. data from individual coal companies).

Forage production and grazing were the most common land uses on the area; principal species were brome (*Bromus* spp), sweet clover (*Melitotus* spp), fescue (*Festuca* spp), and alfalfa (*Medicago* spp). Only a small percentage of land was in row crop production, although this represented the major surrounding land use. Forested tracts, largely volunteer species, were common especially in Knox and Henry counties; cottonwood (*Populus deltoides*), black cherry (*Prunus serotina*), box elder (*Acer negundo*), black locust (*Robinia pseudocacia*), willows (*Ulum* spp), and oaks (*Quercus* spp) were locally dominant.

Impoundments ranged from approximately 0.2 — 60 ha and were characterized by irregular shorelines and numerous islands. Water quality was generally good, supporting a diversity of aquatic macrophytes and invertebrates. Konik (1980) indentified 71 invertebrate taxa in 2 Fulton County lakes and found abundant aquatic vegetation in depths up to 5 m; muskgrass (*Chara* spp), pondweeds (*Potamogeton foliosus*, *P. nodosus*), and southern naiad (*Najas guadalupensis*) were the principal species.

METHODS

Six aerial censuses (Cessna 210 fixed-wing and Enstrom F28-A helicopter) were conducted during 26 March — 30 April and one on 5 June in 1979; 5 were conducted during 18 March — 24 April in 1980 over all of the study area to determine size and distribution of the population. The 4-county study area was outlined on county highway maps and parallel transects were delineated which included all wetlands. Locations of all geese and the percent of paired individuals were

recorded. Single geese exhibiting nest defense behavior along shoreline were recorded as pairs.

Based on aerial surveys and preliminary ground study, several locations were chosen for intensive nest study. The objective was to locate as many nests as possible and record number of eggs, nest type, nest material, and fate of each. During 1980, distance to and height above permanent water, surrounding vegetation, and the dimensions and distance to shore for island nest sites were also recorded. Each nest location was numbered, marked, and recorded by impoundment to facilitate relocation. Active nests were visited at intervals up to 7 days, decreasing to 1 day late in incubation.

Nest initiation was designated as the date the first egg was laid; dates for most nests were calculated by backdating from day of hatch, based on an incubation period of 28 days and a laying rate of 1.5 days/egg (Kossack 1950, Collais and Jahn 1959, Brakhage 1965). Nest success was the proportion of nests which produced 1 or more live goslings; egg success was the percent of all eggs which hatched; and hatching success was the proportion of eggs which hatched after being incubated full term. Nest terminations were classified as successful, destroyed by predator, abandoned, stolen by man, or destroyed by unknown causes. When goslings were not present in the nest, success was determined on the basis of eggshells and membranes characteristic of hatched eggs (Girard 1939, Sowls 1955). Eggs left unhatched in terminated nests were opened to determine cause of failure. Embryo mortality was assumed if the egg contained body tissue, a reddish discoloration near the air cell, or a smear of gray or black material suggesting the breakdown of hemoglobin (Kossack 1950, Cooper and Batt 1972, Raveling and Lumsden 1977). All other eggs were considered infertile.

Identification of the predator responsible for nest destruction was based on (1) appearance of eggshell remains at or near the nest site, (2) measurements between impressions made by paired canines in eggshells, (3) degree of nest disturbance, (4) tracks and scats at the nest site, and (5) guard hairs found stuck to eggshell remains or at destroyed nests. Rearden (1951) desribed waterfowl nest destruction by various predators, and guard hairs were identified using a key by Stains (1958).

Broods were recorded by location, size, and age class (Southwick 1953); only broods of apparent even-age composition were analyzed in an effort to exclude gang broods. On one area where nest searches were complete and all nests were thought located in 1980, total gosling production was compared to number of goslings trapped during July for an estimate of mortality.

RESULTS AND DISCUSSION

Aerial Census

The estimated breeding population on surface-mined areas was 1,698 geese in 1979 and 2,388 in 1980. Because several reports of geese nesting outside surface-mined areas were received in 1979, a sample of unmined areas was included in 1980 aerial census transects. The ratio of potential breeding habitat to goose-use on unmined areas censused was extrapolated to all available breeding habitat in the "pioneer range"; this calculation added 542 geese to the 4-county breeding

population in 1980. Number and surface-water area of impoundments (>0.2 ha) were used as predictors of habitat availability, and the "pioneer range" was delineated by confirmed reports of geese nesting outside mined areas. The level of pair activity (Fig. 2) recorded during censuses, reached peaks of 56.7% on 30 April 1979 and 52.7% on 24 April 1980.

Nest Site Characteristics

Islands were preferred for nesting as 202 of 242 nests were on insular sites. A similar site preference has been described for Canada geese by other studies (Kossack 1950, Geis 1956, Klopman, 1958, Vermeer 1970, Raveling and Lumsden 1977, Giroux 1981). Nesting islands varied in shape, but generally reflected a long, narrow configuration and ranged in size from approximately 6 — 1,000 m^2 with a mean of 175 m^2. Nesting islands varied from 0.2 — 6.0 m above water level, and the majority (61.0%) were within 15 m of shore (Table 1). Nests on islands over 5 m from shore exhibited a much higher success (78%) than those 5 m or less (48%) because of reduced mammalian predation ($T = 2.81$, $P < 0.01$; Table 1). Nests over 5 m from shore were also surrounded by deeper water, usually at least 1-2 m in depth. This study does not support Giroux (1981:676) who suggested islands for waterfowl nesting be at least 170 m from shore to deter predation. Of 26 shore nests monitored in 1980, 23 (88.5%) were on peninsulas, several of which were islands the previous year when water levels were higher.

In 1980 mean distance to water was 1.8 m (0.1 - 9.0 m); 73.6% were 2 m or less. These distances are less than others reported for Canada goose nests (Williams and Sooter 1940, Dow 1943, Craighead and Craighead 1949, Kossack 1950, Klopman 1958, Cooper 1978). Nests on surface-mined lands were often limited to sites near water due to the topography of the surrounding terrain. The mean height above water level for all nests in 1980 was 1.4 m (0.1 - 6.0 m).

Vegetation recorded most frequently in the vicinity of 144 nests were grasses (brome and fescue) 55%, sweet clover 46%, and broad-leaved herbs 39%. Sweet clover was a preferred nest material composing the bulk of 37% of nests, followed by grasses 34% and broad-leaved herbs 15%.

The importance of visibility (Williams and Sooter 1940, Dow 1943, Craighead and Craighead 1949, Miller and Collins 1953, Cooper 1978) appeared to be modified by nest location; shore sites reflected high visibility of surrounding terrain and a minimum avenue of access from the mainland. This characteristic appeared to maximize the probability that the incubating female would be aware of intrusion, thus allowing prompt defense and/or escape. In contrast, Cooper's (1978:27) observations suggested females selected sites with high visibility only when isolated on an island or haystack. The visibility characterisitcs of 118 island nests recorded in 1980 suggested no apparent selection for optimum visibility ($X^2 = 3.10$, $P > 0.20$). In fact, in several island situations, geese selected sites with lower visibility, apparently to decrease visual contact with other nesting geese. If selection of sites with high visibility affords protection against predation (Williams and Sooter 1940, Dow 1943), that factor is probably less important on islands than on shore where encounters with mammalian predators are more likely.

Nest Phenology

The initiation of egg-laying for various populations of *maxima* encompasses

several weeks (Hanson 1965) because of the wide latitudinal distribution of this race. Nesting was begun on 23 March 1979 and 17 March 1980 in west-central Illinois (Table 2); these dates are similar to other *maxima* populations in the Midwest (Kossack 1950, Collias and Jahn 1959, Brakhage 1965, Bednarik 1974, Nigus 1979). All nests were initiated during 22 and 37-day intervals in 1979 and 1980, respectively. Hatching occurred during a 23-day period in 1979, peaking around 8 May; and during a 42-day period peaking around 3 May in 1980. From first egg laid to last egg hatched, the observed span of the nesting season was 57 days in 1979 and 76 days in 1980. Although the nesting period in 1980 might suggest inclusion of continuation nests or second nesting attempts as found by Brakhage (1965) in Missouri, renesting was not recorded.

Productivity

Mean clutch size was 5.7 each year and is among the highest reported for giant Canada geese (Table 3); the range was 3-9 in 1979 and 2-10 in 1980. There was no significant difference between the mean clutch sizes of island nests (5.6, $N = 65$) and shore nests (6.1, $N = 10$) in 1979 ($T = 1.02$, $P = 0.31$), but island nests reflected a higher mean (5.8, $N = 113$) than those on shore in 1980 (5.1, $N = 17$, $T = 2.30$; $P = 0.023$). Field observations suggested that larger clutches on islands in 1980 were a result of earlier nest initiation (Cooper 1978) and a higher proportion of experienced breeders using islands because of intense competition for a reduced number of preferred sites (Hanson 1965, Brakhage 1965, Cooper 1978).

Nest Success. — Out of 242 nests monitored, 181 (74.8%) hatched at least 1 live gosling; this compares favorably with other *maxima* populations (Table 3). Predation accounted for 47 losses, 9 nests were abondoned, 2 were robbed by man, and 3 were undetermined.

Nests on preferred island sites were more successful (82.2%) than those on shore (37.5%; $T = 5.5$, $P < 0.001$). Nest success in 1980 was significantly lower than in 1979 ($T = 2.58$, $P < 0.01$, Table 4), reflecting a substantial increase in nest predation from 8.4% in 1979 to 25.2% in 1980.

Egg Success. — Egg sucess which averaged 76.5% was 81.6% in 1979 and 73.5% in 1980. Predation, the largest source of failure, accounted for 194 eggs (15.5%). Other sources of egg failure were embryo mortality 32 (2.6%), nest abandonment 16 (1.3%), infertile 14 (1.1%), displaced 12 (1.0%), stolen by man 12 (1.0%), dumped 2 (0.2%), and unknown 13 (1.0%). These results were similar to those in Missouri (Brakhage 1965) and Iowa (Nigus 1979), but were higher than those of several other *maxima* flocks (Table 3).

Hatching Success. — Overall hatching success averaged 96.8%; it was 95.4% in 1979 and 97.7% in 1980. Eggs in shore nests exhibited a slightly higher hatching success (100%, $N = 80$), compared with 96.5% ($N = 910$) for island nests ($X^2 = 2.91$, $P > 0.09$, Table 4). Because over 50% of shore nests were destroyed by predators, females successful in incubating clutches full term on shore were probably the most tenacious. Raveling and Lumsden (1977:40) observed higher predation of nests where the female left more often or fled secretively upon intrusion by investigators. It follows that in the absence of many predators capable of killing an adult goose and the presence of a high density of nest-destroying predators, a high level of tenacity and defense would both decrease the chance of nest predation and increase egg hatchability.

Nest Predation. — Predation, the largest factor contributing to nest and egg failure during both years, was higher (25.2%) in 1980 than in 1979 (8.4%; X^2 = 9.7%, $P < 0.002$). With lower water levels in 1980, predation of island nest increased from 0% in 1979 to 19.5%. There were fewer isolated sites in both distance and water depth, resulting in greater predator accessibility. Density of nesting pairs at several sites increased markedly in 1980; the most extreme was one site which reflected 2.15 nests/usable ha in 1979 and 4.65 nests/usable ha in 1980. That area exhibited the highest increase in predation from 0% to 41%. As a result of higher nest densities which increased intraspecific strife and use of marginal nesting habitat, some females spent more time off the nest which enhanced predation. This finding supports that of Sherwood (1965) in studies at Seney, Michigan.

Raccoons were incriminated in 24 of 52 nest predations; 20 were on islands and 4 on shore. Nine nest losses on shore were attributed to striped skunk (*Mephitis mephitis*), 6 were suspected destroyed by dog or coyote (*Canis latrans*), and 13 were lost to unknown predators.

Nest desertion, found to be the major cause of nest failure by others (Geis 1956, Hanson and Eberhardt 1971, Ewaschuk and Boag 1972, Cooper 1978, Nigus and Dinsmore 1980) was unusually low (3.7%) in this study. Field observations supported Cooper (1978:63-64) who suggested that most deserting females never attained normal nest attentiveness and their mates contributed little to nest defense. These characteristics were also recorded for many of the pairs which lost nests to predators. The evidence suggested virtually all nest predation occurred while the female was absent from the nest site; and because most deserted nests were destroyed within 2 days, predators were seemingly aware of many nest locations but were unsuccessful in displacing attentive geese or reluctant to attempt it. Therefore, geese characteristically less tenacious were more likely to lose nests to predators. Regardless of the proximate cause of nest failure (predation or desertion), the ultimate cause may gave been maladaptive behavioral traits as proposed by Raveling (1981).

Broods

A total of 101 broods of apparent even-age compostion was observed; 41 in 1979 and 60 in 1980. However, the effort to exclude gang broods was unsuccessful; mean brood size decreased from 5.3 to 5.2 between class Ia and Ib broods, but increased to 5.4, 5.6, and 5.9 for classes IIa. IIb, and III, respectively. Warhurst (1974) reported that average brood size was over 2 goslings higher than the mean hatch per successful nest as a result of "ganging"; Williams and Marshall (1938), Miller and Collins (1953), and Geis (1956) observed similar increases.

Gosling mortality was estimated by comparing number of goslings produced on an isolated production area where all nests were located, with the number captured during the molt. During 1980 that area had 12 nests which yielded 56 goslings; 45 goslings were captured in July indicating a mortality of 19.6% between the hatch and the molt. Warhurst (1974) estimated a 15% mortality rate for goslings reared unconfined in a marsh at Crane Creek Wildlife Area, Ohio.

CONCLUSIONS

The population of giant Canada geese nesting in west-central Illinois is highly productive and is increasing in numbers and distribution. Quality of habitat, as afforded by impoundments resulting from surface mining, provides safe desirable nesting conditions (islands) and diversity of wetlands. Land use practices and associated forage production on uplands seem to provide satisfactory food supplies and nest cover. The vigor of this population should result in higher breeding populations and expansion into presently unoccupied habitat. Although predation was the largest factor limiting production, its effect was not severe. Further research into gosling survival and proportion of paired geese which do not attempt to nest is in order; this information would allow development of a workable model to estimate recruitment from counts of paired geese during the breeding season.

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Table 1. Success of 118 island nests versus distance to shore (m) for nesting islands in west-central Illinois, 1980.

	Distance from Shore (m)								
	5	6-10	11-15	16-20	21-25	26-30	31-35	36-50	50
Successful	12	19	16	5	13	3	4	12	4
Unsuccessful	13	3	4	0	3	0	2	3	2
Total	25	22	20	5	16	3	6	15	6

Table 2. Nest phenology of giant Canada geese in west-central Illinois, 1979-1980.

	Egg-laying Period	Incubation Period
1979		
First Nest (4 eggs)	23 March-28 March	29 March-26 April
Last Nest (5 eggs)	13 April-20 April	21 April-18 May
Peak Nesting Period	2 April-10 April	11 April-8 May
1980		
First Nest (4 eggs)	17 March-22 March	23 March-20 April
Last Nest (7 eggs)	22 April-2 May	3 May-31 May
Peak Nesting Period	27 March-4 April	5 April-3 May

Table 3. Clutch size, nesting success, and productivity reported for several populations of *Branta canadensis maxima*.

Location and Source	Year(s)	N	Mean Clutch Size	Nest Success (%)	Egg Success (%)	Hatching Success (%)	Goslings per Nesting Pr.	$\bar{x}$ Brood Size at Hatching
Dog Lake, Manitoba Klopman 1958	1954-55	104	5.1	46	51.4	96	-	-
Barrington, IL Kossack 1950	1945-46	140	5.0	57	55.6	-	-	-
Trimble, MO Brakhage 1965	1961-64	147	5.6	65	73	78	4.1	-
Marshy Point, Manitoba Cooper 1978	1969-71	473	5.6	75	67	97	3.8	5.1
Northwestern IA Nigus 1979	1977-78	211	6.0	79	77	86	4.2	5.3
Southeeastern MI Kaminski et al. 1979	1974-75	146	5.4	82	70	91	-	-
Mosquito Creek, Killdeer Plains, Mercer County, and Crane Creek, OH Bednarik 1974	1974	966	5.0	75	72	-	-	-
Central IL This Study	1979-80	242	5.7	74.8	76.5	96.8	4.0	5.2

Table 4. Relationship of nest site to clutch size, nesting success and ultimate productivity for giant Canada geese in west-central Illinois, 1979-1980.

	1979			1980			79-80
	Island	Shore	Total	Island	Shore	Total	Total
Nests Observed	69	14	83	133	26	159	242
Successful Nests	64	6	70	102	9	111	181
Nest Success (%)	92.8	42.9	84.3	76.7	34.6	69.8	74.8
Totally Predated Nests	0	7	7	26	14	40	47
Nests With Complete Clutches	65	10	75	113	17	130	205
Eggs Comprising Complete Clutches	366	61	427	658	87	745	1172
Mean Clutch Size	5.6	6.1	5.7	5.8	5.1	5.7	5.7
Eggs Laid	377	79	456	694	103	797	1253
Eggs Hatched	333	39	372	545	41	586	958
Egg Success (%)	88.3	49.4	81.6	78.5	39.8	73.5	76.5
Fertile Eggs Incubated							
Full Term	351	39	390	559	41	600	990
Hatching Success (%)	94.9	100	95.4	97.5	100	97.7	96.8
Mean Brood Size At Hatching	5.1	6.5	5.3	4.6	5.2	5.2	
Goslings Produced Per Nesting Pair	4.8	2.8	4.5	4.1	1.6	3.7	4.0

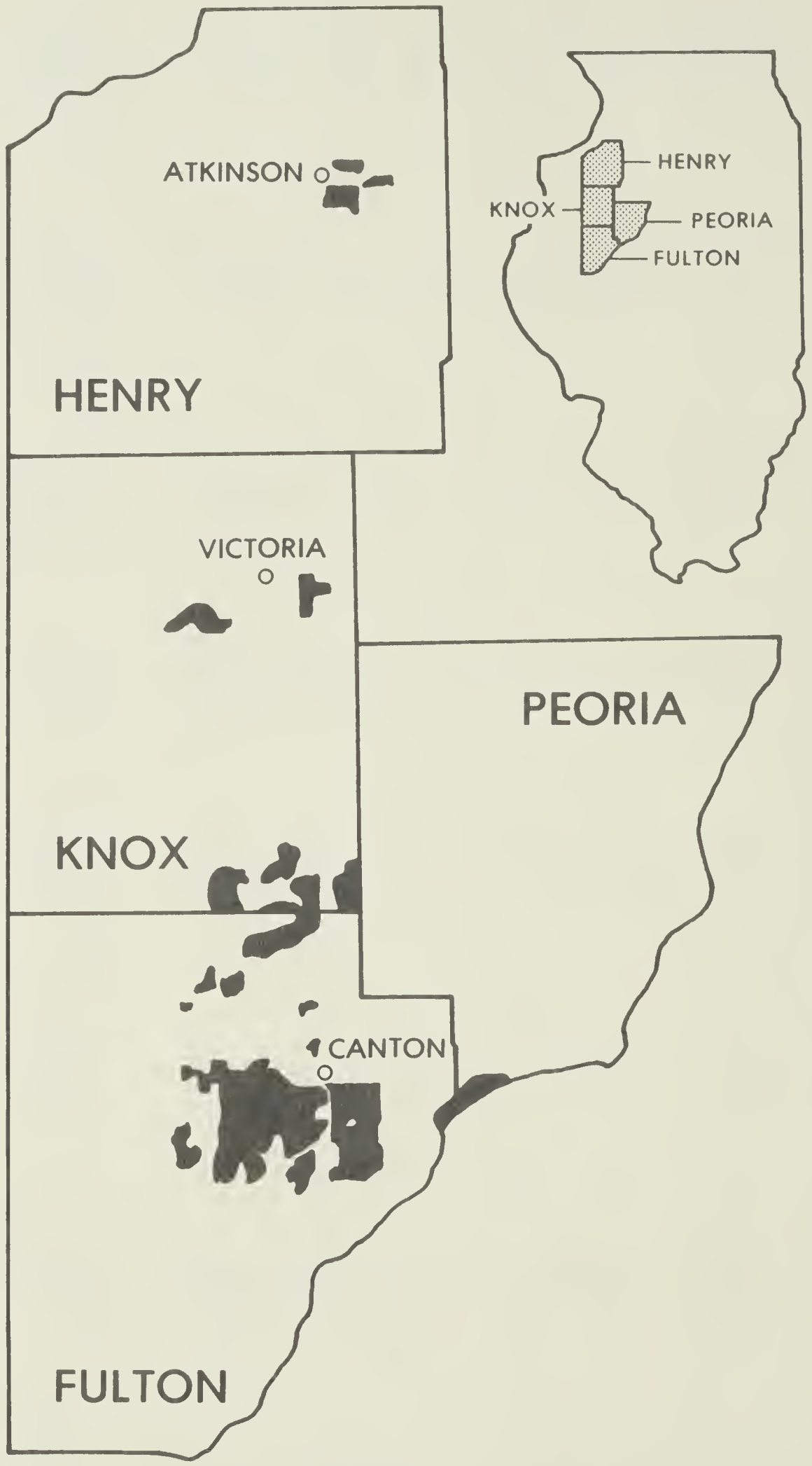

Figure 1. Giant Canada goose production areas in west-central Illinois.

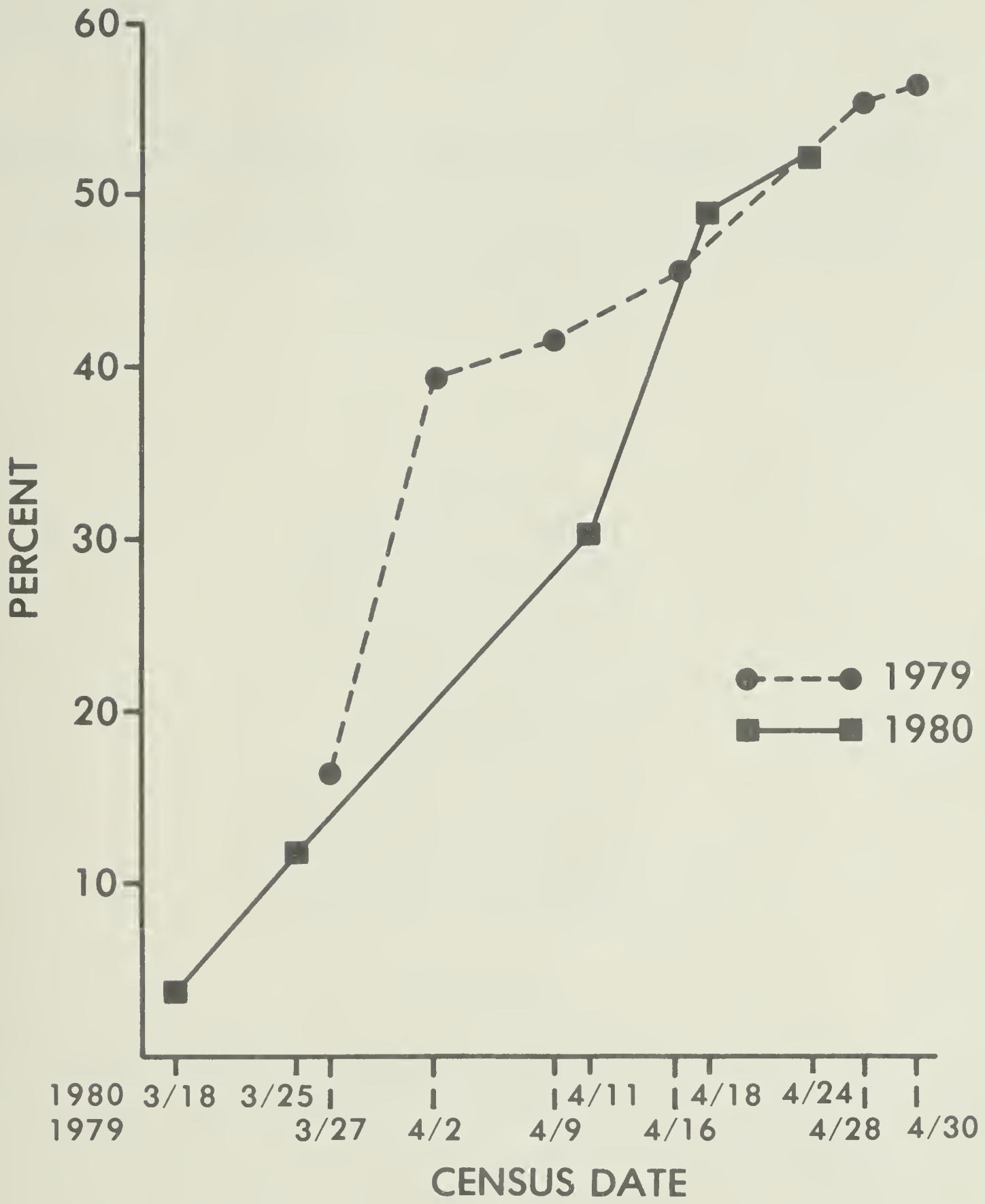

Figure 2. Proportion of geese recorded as paired during aerial censuses in west-central Illinois, 27 March - 30 April 1979, and 18 March - 24 April 1980.

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HEARTWORMS (*DIROFILARIA IMMITIS*) IN COYOTES (*CANIS LATRANS*) IN ILLINOIS

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ABSTRACT

Dirofilaria immitis was found in 103 of 472 (21.8%) coyotes (*Canis latrans*) collected from fur buyers and trappers in 28 Illinois counties during 1977 through 1980. The overall prevalence rate was 9.4% in the northern one-half of the state compared with 23.8% in the southern one-half. In southeastern Illinois where 28.0% of all coytes examined were infected, the prevalence rate for juveniles was significantly lower than that for adults. Infection levels ranged from 1 to 52 heartworms per animal and averaged 9.6. In general the mean number of worms per infection in adults was higher than in juveniles. Ten of 29 (34.5%) coyotes from Clay and Richland counties had single sex heartworm infections. The parasite sex ratio was 1.11:1, female to male. The finding of *D. immitis* in coyotes represents a new host record for the state.

INTRODUCTION

The first report of heartworm (*Dirofilaria immitis*) in a coyote (*Canis latrans*) was made in 1924 in Missouri (see reference in Otto 1975). For many years most studies revealed low prevalence rates in comparison with dogs (*Canis familiaris*)

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from the same localities suggesting that coyotes did not constitute any reservoir problem (Otto 1972, 1975). However, recent reports, which document high prevalence rates in coyotes from California (Weinmann and Garcia 1980), Louisiana (Crowell et al. 1978), and the Gulf Coast of Texas and Louisiana (Custer and Pence 1981), indicate a need to consider this wild canid as a potential reservoir host in areas where heartworms are prevalent. Illinois is such an area. Domestic canine infections are consistently diagnosed throughout the state (Noyes 1978) with prevalence rates as high as 48% being encountered (Otto 1972). Also, *D. immitis* has been found to infect both red foxes (*Vulpes vulpes*) (Hubert et al. 1980, Dyer and Klimstra 1981) and gray foxes (*Urocyon cinereoargenteus*) (Dyer and Klimstra 1982, Hubert et al. 1982) in several southern Illinois counties.

Cardio-pulmonary deficiencies caused by *D. immitis* are probably more serious in a highly active predator like the coyote than in a domestic dog (Gier and Ameel 1959), but the effects of heartworm on the health or liveability of coyotes remain uncertain (Gier et al. 1978). Some of the basic information about characteristics of heartworm infections in coyotes needed to assess these effects is becoming available. For example, Graham (1975), Crowell et al. (1978), Weinmann and Garcia (1980), and Agostine and Jones (1982) reported age-specific prevalence rates among host coyotes, the number, sex ratio, and length of *D. immitis* recovered from coyotes, and the prevalence of circulating microfilariae. Comparative data for Illinois are not available even though coyotes are common throughout the state. Fur-takers harvested an average of 7,600 coyotes (1 per 19.2 km^2) in Illinois annually from 1975 through 1982 (Hubert, unpublished data).

The primary objective of our study was to determine the prevalence of heartworm in coyotes throughout Illinois. In addition, we collected information about the characteristics of *D. immitis* infections in coyotes from the southeastern part of the state.

MATERIALS AND METHODS

Coyote carcasses were collected from fur buyers during November 1977-February 1978, November 1978-March 1979, and October 1979-February 1980. These fur buyers were located in Clay, Clinton, DeKalb, Edgar, Hancock, Jasper, Livingston, Menard, Moultrie, and Richland counties. Although precise capture locations were not available for some animals, all were captured in Illinois within the following radii of the various furhouses where obtained: Clay and Richland counties, 100 km; DeKalb, Edgar, Hancock, and Livingston counties, 80 km; Clinton County, 48 km; Jasper County, 32 km; Moultrie County, 24 km; and Menard County, 16 km. Additional coyote hearts from specimens caught during November-December 1977 in Bond County, November-December 1978 in Bond and Pope counties, and October-December 1979 in Carroll, Ford, Knox, and Mason counties were supplied by cooperating trappers.

Several carcasses were frozen when received and subsequently thawed for heart removal. Hearts collected by cooperating trappers were frozen; these were also thawed prior to examination. Ventricles, atria, and pulmonary arteries were inspected macroscopically for heartworms. All worms were indentified and, if possible, sexed according to Yorke and Maplestone (1969). Representative specimens of *D. immitis* have been deposited in the U.S. National Parasite Collection, Beltsville, Maryland (Accession No. 75856).

Age was determined only for those coyotes collected in southeastern Illinois from which skulls were available. Coyotes were assigned to 1 of 2 age classes based on canine tooth characteristics (Linhart and Knowlton 1967). Animals less than 1 year old were classified as juveniles; those older were considered adults.

Statistical comparisons of prevalence rates were accomplished with chi-square tests (Snedeor and Cochran 1967:215). Relationships between mean parasite burdens and the sex and age of infected coytes were evaluated using the *t*-test for unequal sample sizes (Snedecor and Cochran 1967:104). Significance was determined at the 0.05 level of probability.

RESULTS

Specimens of *D. immitis* were collected from 103 of the 472 (21.8%) coyotes examined (Table 1). Fifty-seven of 246 (23.2%) male coyotes and 46 of 223 (20.6%) females were infected; the difference was not significant ($\chi^2 = 0.44$, 1 df, $p > 0.30$). In the northern one-half of Illinois the overall pervalence rate was 9.4% compared with 23.8% in the southern one-half. This difference was significant ($\chi^2 = 6.72$, 1 df, $p < 0.01$).

Adult heartworms occurred in 49 of 175 (28.0%) coyotes checked at furhouses in Clay and Richland counties in southeastern Illinois (Table 2). All nematodes found were in the right atrium and frequently extended into the pulmonary artery. Prevalence rates for juvenile male coyotes (20.3%) and juvenile females (15.3%) did not differ significantly ($\chi^2 = 0.55$, 1 df, $p > 0.30$), but those for adult males (45.5%) and adult females (78.6%) did ($\chi^2 = 4.36$, 1 df, $p < 0.05$). The difference between the prevalence rate for all juvenile coyotes (18.0%) and that for all adults (55.3%) was also significant ($\chi^2 = 23.79$, 1 df, $p < 0.01$).

The level of infection (worm burden) in coyotes from southeastern Illinois ranged from 1 to 52 and averaged 9.6 (Table 2). The mean worm burdens for male (12.8) and female (2.9) juvenile coyotes and those for male (8.4) and female (12.9) adult coyotes did not differ significantly ($t = 1.39$, 15 df, $p > 0.10$; $t = 1.00$, 20 df, $p > 0.30$) by sex. Also, there was no significant difference ($t = 0.37$, 37 df, $p > 0.70$) when the average level of infection for juveniles (8.7) was compared with that for adults (10.2). However, the latter comparison was largely influenced by two juvenile males that harbored 42 and 52 worms, respectively.

Ten of 29 (34.5%) infected coyotes collected in Clay and Richland counties, and from which all heartworms could be sexed, had single sex infections. These included 6 unisexual infections among 12 juveniles and 4 among 17 adults. The parasite sex ratio among these host animals was 1.11:1, female to male ($n = 293$).

DISCUSSION

No previous records of heartworms in coyotes in Illinois exist although infections have recently been documented in adjacent states (Franson et al. 1976, Kazacos 1977). Our data indicate the prevalence of heartworm infection in Illinois coyotes is among the highest reported in the United States. Only California (37%) (Weinmann and Garcia 1980), Louisiana (58%) (Crowell et al. 1978), southern Texas (23%) (Thornton et al. 1974), and the coastal prairies of Texas and Louisiana (71%) (Custer and Pence 1981) show higher levels. However, sample sizes in the latter two studies were small (<25). Prior to our study, the highest

prevalence rate in the central United States was 8% reported in Kansas and Colorado (Graham 1975). Perhaps the incidence of heartworms in midwestern coyotes has increased substantially during the last 5 to 8 years, or conditions in Illinois are more suitable for development and transmission of this parasite than in surrounding areas.

The prevalence rate in coyotes was over 2.5 times greater in southern Illinois than in the northern one-half of the state. Marquardt and Fabian (1966) reported a similar pattern in dogs. The longer breeding season for mosquitoes is southern Illinois (Ross 1947) probably contributes to this variation, but other factors may be involved because high prevalence rates have been recorded for dogs examined in extreme northeastern Illinois counties (Otto 1972).

No significant difference in overall prevalence rates for male and female coyotes was detected; this is consistent with the findings of Graham (1974) for dogs and Weinmann and Garcia (1980) for coyotes. Therefore, the significant difference in prevalence rates between sexes of adult coyotes in southeastern Illinois probably reflected sampling variability. However, behavioral differences between male and female adult coyotes, especially those associated with movement patterns and the rearing of young, may increase the likelihood of adult females becoming infected. Additional research is needed to clarify the situation.

The significantly higher prevalence rate observed among adult coyotes compared with juveniles parallels findings of Graham (1975), Crowell et al. (1978), Weinmann and Garcia (1980), and Custer and Pence (1981). Obviously adult coyotes have been exposed longer, thus increasing their chances of becoming infected. In addition, we observed older coyotes generally, but not always, had higher mean worm burdens than younger coyotes as did earlier researchers. Up to 52 adult heartworms were recorded from a juvenile coyote. In contrast, the highest worm burden previously reported for a juvenile was six (Graham 1975).

The effect of heartworms on the health of coyotes is not clear. Jackson et al. (1966) reported that 25 worms in dogs gave no indication of disease, but 47 to 58 worms resulted in moderate to severe disease. Maximum heartworm burdens reported previously in midwestern coyotes varied from 12 in Kansas (Graham 1975) to 23 in Iowa (Franson et al. 1976); our study documented a maximum of 52. Burdens exceeding 50 worms per animal have also been encountered in other areas (Crowell et al. 1978, Weinmann and Garcia 1980, Custer and Pence 1981). These data, plus results of clinical studies on cardiopulmonary lesions of captive coyotes infected with heartworms (Ross and Suzuki 1973) support the suggestion (Crowell et al. 1978) that *D. immitis* may limit coyote populations in enzootic areas.

Our findings of 1.11 female heartworms for each male are consistent with those reported by Weinmann and Garcia (1980) and Custer and Pence (1981). In contrast Agostine and Jones (1982) documented 2.2 females per male in New Hampshire from a sample of eight positive coyotes. The female:male ratio is frequently above unity in many nematode infections and is positively correlated with the intensity of infection; the female:male ratio decreases as worm burdens increase (Young and Pence 1979). Overall, most data appear to indicate the female:male ratio in heartworm infections in coyotes is near 1:1 and not significantly affected by the intensity of infection.

Within the last 15 years researchers have suggested that the coyote is an unnatural host for *D. immitis* and thus a poor reservoir of infection because of low

prevalence of infection, low worm burdens, preponderance of singe-sex infections, and/or the failure of heartworms to produce microfilariae (Otto 1969, 1972, 1975, Graham 1975). Graham (1975:515) proposed that "*D. immitis* must be transmitted to coyotes by mosquitoes from infected dogs, and the occurrence of heartworm in coyotes is of no importance to a dog population." However, 2 years earlier Monson et al. (1973) recognized coyotes as a possible reservoir for heartworm infection in dogs. It was suggested for coyotes to serve as a reservoir host they must be capable of supporting full development of the heartworm to sexual maturity and microfilarial production. Coyotes are now known to fulfill both requirements. Over 65% of the positive coyotes examined from Clay and Richland counties for which complete data are available harbored both sexes of adult heartworms. Weinmann and Garcia (1980) reported bi-sexual infections in 63% of the positive coyotes checked. Also, uterine microfilariae were present in 82% of the 280 female heartworms they recovered, and microfilariae were abundant in lung smears from all positive coyotes harboring mature male and female *D. immitis*. Our data on prevalence rates, mean worm burdens, and incidence of bi-sexual infections in coyotes support Weinmann and Garcia (1980) in that the coyote appears to be as suitable a host for *D. immitis* as the dog and is likely a reservoir of infection in certain areas. Crowell et al. (1978) and Custer and Pence (1981) agree. Further study of microfilarial development and transmission along with infectivity trials to more clearly delineate the coyote's role in the epizootiology of canine heartworm disease should be pursued, especially where preventive programs for dogs have been instituted.

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Table 1. Prevalence of *Dirofilaria immitis* in coyotes collected in Illinois, November 1977-February 1978, November 1978-March 1979, and October 1979-February 1980.

County	Male	Female	Sex unknown	Totals
North of 40° N. Latitude				
Bureau	1/3[b]	–	–	1/3
Carroll	–	0/1	–	0/1
DeKalb	0/1	0/2	–	0/3
Ford	0/4	1/3	–	1/7
Hancock	0/1	0/1	–	0/2
Henderson	0/1	1/5	–	1/6
Kane	0/1	0/3	–	0/4
Knox	2/10	1/15	–	3/25
LaSalle	0/3	–	–	0/3
Lee	–	0/1	–	0/1
Livingston	0/1	0/1	–	0/2
Mason	0/4	0/1	–	0/5
McHenry	–	0/1	–	0/1
Mercer	–	0/1	–	0/1
Subtotals	3/29	3/35	–	6/64
South of 40° N. latitude				
Bond	3/29	8/45	–	11/74
Clark	–	0/1	–	0/1
Clay[a]	14/52	10/42	–	24/94
Coles	–	0/1	0/1	0/2
Edgar[a]	13/33	9/35	–	22/68
Jasper[a]	1/5	1/2	0/1	2/8
Jefferson	1/13	1/5	–	2/18
Marion	0/1	–	0/1	0/2
Menard[a]	0/2	0/3	–	0/5
Moultrie[a]	–	0/4	–	0/4
Pope	–	0/1	–	0/1
Richland[a]	19/72	14/47	–	33/119
Shelby	0/1	–	–	0/1
Washington	3/9	0/2	–	3/11
Subtotals	54/217	43/188	0/3	97/408
Statewide				
Totals	57/246	46/223	0/3	103/472

[a]Exact origin uncertain; county indicates location of furhouse where animal was examined.
[b]Number infected/number examined.

Table 2. Characteristics of *Dirofilaria immitis* infections in coyotes collected from fur buyers in Clay and Richland counties, Illinois, January 1978-January 1980.

Age-sex of coyote	Number positive / Number examined	Parasites per infection			
		N	Mean ± SE	Range	Total
Juvenile male	14/69 (20.3)[a]	10	12.8 ± 5.9	1-52	128
Juvenile female	9/59 (15.3)	7	2.9 ± 1.1	1-9	20
Adult male	15/33 (45.5)	13	8.4 ± 2.3	1-25	109
Adult female	11/14 (78.6)	9	12.9 ± 4.2	1-41	116

[a]Numbers in parentheses indicate percent positive.

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ASBESTOS EXPOSURE, CIGARETTE SMOKING, AND PULMONARY FUNCTIONS

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ABSTRACT

A comprehensive health screening program consisting of standardized health and occupational history questionnaire, pulmonary function testing, chest x-ray, blood chemistry and urinalysis was organized for the Asbestos Workers Union Local No. 1 in St. Louis, Missouri. One hundred and thirty-five male caucasian workers or 44% of the membership volunteered to participate, and the pulmonary function testing data for all 135 workers were grouped according to their number of years of exposure to asbestos and their personal smoking habits. In general, smokers have significantly lower pulmonary functions than non-smokers and ex-smokers. When the number of years of exposure to asbestos is greater than 20, the pulmonary functions of non-smokers are significantly better than the ex-smokers. This study also shows that working in the asbestos industry can cause decreases in pulmonary functions regardless of whether or not a worker smokes.

INTRODUCTION

Asbestos is a general name for a large group of hydrated silicates that, when crushed or milled, separate into flexible fibers. The group is a continuous solid solution series of minerals that represents a small part of a larger mineral group of fibrous materials, the amphiboles. Since this class of minerals is a solid solution series, the chemical composition varies considerably from locality to locality and from one class member to another.

Asbestosis was recognized as a respiratory disease very early and led to the development of some of the first standards regulating dust levels in the workplace (Levin 1978). Asbestos in man involves diffuse interstitial fibrosis, calcification and fibrosis of the pleura, broncogenic carcinoma, and mesothelial tumors (Selikoff and Lee 1979). All amphiboles appear to be capable of initiating symptoms in man and the organization of the surface of the fibers, their lengths, and their diameters seems critical in the production of biologic effects (Becklake 1976, Churg and Warnok 1979).

Bronchogenic carcinoma and mesothelial tumors in man rarely occur less than 30 years after exposure to asbestos. Other environmental and personal habits exposing workers to other carcinogens or potential carcinogens further complicate the interpretation of the incidence of cancer following asbestos exposure. Smoking appears to enhance bronchogenic cancer and mesothelial tumor production (Selikoff et al. 1968, Burrows et al. 1977, Buist et al. 1979).

We determined to study the relationship between years of asbestos exposure and cigarette smoking on the pulmonary health of asbestos workers. To accomplish this, a comprehensive health screening program consisting of standardized health and occupational history questionnaire, blood chemistry profile, complete blood count, urinalysis, chest radiographs, and pulmonary function testing was organized for the Asbestos Workers Union Local No. 1 in St. Louis, Missouri. The program was made available on a voluntary basis to all members in the Union.

MATERIALS AND METHODS

During the evenings of the first week of June, 1981, 140 members of the Asbestos Workers Union Local No. 1, St. Louis, Missouri, volunteered to participate in a comprehensive health screening program. The other 170 members elected not to participate for personal reasons. According to Union records, these 170 individuals appeared to represent a cross-section of the Union similar to the 140 participants. They were fairly well distributed according to age, time span of asbestos exposure, and history of illness. On the surface, there appeared to be nothing remarkable in this group which would tend to skew the obtained study results.

The 140 participants consisted of 1 caucasian female, 4 black males, and 135 caucasian males. To assure a homogeneous study population, only the data for the 135 caucasian males were used in this study. Each participant was interviewed and completed a standardized health and occupational history questionnaire. All participants received the same battery of screening tests which included blood chemistry profile, complete blood count, urinalysis, chest x-ray, and pulmonary function testing.

Ventilatory function was assessed by recording the forced vital capacity using a Collins Eagle One Spirometry System, which was periodically and routinely checked for calibration. This unit, which meets all ATS-OSHA performance standards (Gardner et al. 1979), consists of a modified Stead Wells spirometer with kymograph and potentiometer, micro-processor, and a line printer. As the subject inhales and then exhales maximally, the resulting forced vital capacity curve is graphically displayed on the spirometer kymograph. The potentiometer signals are fed into the micro-processor, which calculates the flows and volumes, corrects them for BTPS (body temperature, pressure, saturated) conditions, and displays the test parameters on the digital screen. In addition, these parameters are printed out by the line printer.

The flow range of the Collins Eagle One Spirometry System is 0.0 to 20.0 L/sec, with an accuracy of 0.1 L/sec. The volume range is 0.0 to 9.99 L, with an accuracy of 0.025L. The parameters measured include the actual forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), the ratio of forced expiratory volume in one second to forced vital capacity (FEV_1/FVC), peak expiratory flow rate (PEFR), and forced expiratory flow during the mid-portion of the

FVC curve (FEF_{25-75}). Predicted normal equations based on age, height, sex, and race for adults (Knudson et al. 1976) are internally programmed. The predicted value and % predicted for the measured values are automatically generated and printed out at the completion of the study.

Each participant was carefully coached as to the proper method for performing an acceptable FVC curve, and the procedure was demonstrated (Cissik and Salustro 1977). Each participant then produced at least three acceptable FVC curves. Acceptability was defined and based on OSHA standards for cotton dust (USDOL 1978). Among others, these standards include continuing expiration for at least 6 seconds or until an obvious plateau in the volume-time curve occurs, and variation between the two largest FVC and FEV_1 measurements not exceeding 10% or 100 mL, whichever is larger. With each curve, a permanent alphanumeric record of the test results was printed out. The micro-processor also summarized the results and the summary results were used in the statistical analysis.

RESULTS

Data were collected from 135 male caucasian workers. Chemistry profile and urinalysis indicate that all test results were within normal limits. Pulmonary abnormalities were seen on 22 of the 135 chest radiographs. Eighteen of these, demonstrating such abnormalities as overinflation, tubular shadows, prominent linear markings, oligemia, and/or pulmonary hypertension, were consistent with a chronic airflow obstruction (Fraser and Pare 1979, Guenther and Welch 1977). The other four, showing differing extent and profusion of small opacities, pleural thickening, and pleural calcification, were consistent with varying grades of asbestosis according to the ILO U/C 1971 classification system (Fraser and Pare 1979). The remaining 113 chest radiographs demonstrated no significant pulmonary abnormalities.

The pulmonary function testing results for all 135 asbestos workers were separated into two subgroups based on their work history. Because Fraser and Pare have indicated that development of clinical manifestations requires a minimum of 20 years after onset of exposure to asbestos, we elected to look at our subjects in terms of those with less than 20 years of continuous work exposure (66 members) and those with more than 20 years of continuous work exposure (69 members). Within each group, the workers were further divided into three subgroups according to their smoking history, namely, non-smokers, ex-smokers, and smokers. A non-smoker was a person who had never smoked regularly. An ex-smoker was a person who had abstained from smoking for at least one year. A smoker was a person who had smoked regularly. The 66 workers with less than 20 years of continuous asbestos exposure consisted of 19 non-smokers, 11 ex-smokers, and 36 smokers, and among the 69 workers with more than 20 years of continuous work exposure: 17 non-smokers, 23 ex-smokers, and 29 smokers.

It was interesting to note that of the 22 workers with abnormal chest x-rays, there was only one non-smoker, but there were 10 ex-smokers and 11 smokers. The average period of time for ex-smoking was 10 years with the range being from 4 to 22 years. Analysis of the data from these 22 individuals showed this group to consist of middle-aged (50.68 ± 8.73 years) men with a mean work history in the asbestos industry of 29.37 ± 8.89 years.

The means and standard deviations of pulmonary functions of the 6 sub-

groups were calculated and are presented in Table 1. Table 2 shows the coefficient of correlation among pulmonary function measurements in the 135 workers. Significant correlation was observed between various pulmonary function parameters at the $p < 0.01$ level. Multiple-regression equations relating pulmonary function parameters to age, smoking habit, and years of asbestos exposure are given in Table 3 for all workers in the study, Table 4 for non-smokers, Table 5 for ex-smokers, and Table 6 for smokers. The correlation coefficients are all significant at the $p < 0.05$ level.

DISCUSSION

Asbestos, a natually occurring fibrous material, is an example of a material uniquely useful, because of its physical and chemical properties, and at the same time hazardous to man. Evidence linking inhalation of asbestos fiber to the development of a group of diseases is generating ever-growing concern. The demonstrated risks include the worker exposed in manufacture and use of asbestos, residents of neighborhoods of asbestos manufacturing plants, and the members of households of the asbestos worker.

In the group of workers with less than 20 years of asbestos exposure, the FVC, FEV_1, PEFR, and FEF_{25-75} were all within normal limits for the non-smokers and ex-smokers. Normal limit was defined as 80% or better of the predicted value. While the smokers in this group had normal FVC, FEV_1, and PEFR, their FEF_{25-75} had a mean value of 67.58% which was considered to have mild impairment. Mild impairment was defined as 65-79% of the predicted value.

In the group of workers with more than 20 years of asbestos exposure, the FVC, FEV_1, and PFER were also within normal limits. The FEF_{25-75}, however, had a mean value of 68% for the non-smokers, indicating mild impairment, while the ex-smokers and smokers had mean values of 49.17% and 51.10% respectively. These workers were considered to have moderate impairment which was defined as 50-64% of the predicted value. In both groups, the smokers demonstrated lower forced mid-expiratory flow rates than the non-smokers and ex-smokers. However, with more than 20 years of asbestos exposure, the forced mid-expiratory flow rates were significantly much lower than the predicted normal values for all three sub-groups of workers. This seems to indicate that long-term asbestos exposure has a deleterious effect on lung function. The large change in the FEF_{25-75} would particularly suggest that asbestos not only causes a fibrotic condition but also can affect the small airways (Fraser and Pare 1979).

It has been suggested that with the cessation of cigarette smoking, ventilatory functions improved over a period of at least 6 to 8 months (Buist et al. 1979). Our data showed that while there were no significant differences in the ventilatory functions between the non-smokers and ex-smokers in the group with less than 20 years of asbestos exposure, the ex-smokers in the group with more than 20 years of asbestos exposure showed a statisitically significant difference in FVC, FEV_1, and FEF_{25-75}. It would appear that a significant improvement cannot be expected for a person who has worked for more than 20 years in the asbestos industry. It appears that cessation of cigarette smoking is particularly beneficial to those workers with less than 20 years of asbestos exposure. Recently, it has been suggested that smokers might even be better off than the ex-smokers who had damaged their lungs by long exposure to cigarette smoking, asbestos work, or a combination of

both (Corbin et al. 1979). The smoker exhales as a result of his smoking habit, while the ex-smoker no longer exhales as deeply. As a result, potentially harmful asbestos fiber is not exhaled by the damaged lung. The smoker in the process of smoking might exhale more of the asbestos fibers that penetrated into the lungs. If this hypothesis was correct, then deep breathing exercise performed regularly can certainly help the workers to eliminate some of the harmful asbestos fibers from the respiratory system.

CONCLUSIONS

In conclusion, our data show a significant difference in pulmonary function between smokers and non-smokers/ex-smokers in general, and ex-smokers do not have significantly better pulmonary function tests than do the smokers when both have more than 20 years of asbestos exposure. In all workers, the FEF_{25-75} ranges from the low end of the normal limit to moderate impairment depending on the smoking habit and the number of years of asbestos exposure for the individual. The pulmonary functions are significantly different when the older and younger non-smokers are compared, yet there are fewer functions that had significant differences when the older smokers, ex-smokers, and non-smokers are compared. Our data also show that working in the asbestos industry can damage the lung functions regardless of whether or not the worker smokes.

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Table 1. Means and Standard Deviations of Pulmonary Functions of 135 Male Asbestos Workers Based on Exposure and Smoking History.

Parameters	All Workers	20 Years of Exposure			20 Years of Exposure		
		Non-Smokers	Ex-Smokers	Smokers	Non-Smokers	Ex-Smokers	Smokers
Age (Years)	42.63	28.89	32.73	35.69	50.65	50.26	50.86
	12.44	6.90	9.36	10.49	7.77	6.22	6.80
Asbestos Exposure (years)	19.91	8.89	10.45	11.39	29.76	30.48	27.14
	10.83	5.52	5.89	5.03	6.73	6.32	6.32
Smoking (Packs/day-year)	21.77	0.00	11.82	20.81	0.00	32.57	45.59
	21.92	0.00	13.21	13.83	0.00	18.98	19.41
FVC (L)	4.70	5.53	5.55	4.87	4.25	4.17	4.35
	0.95	0.74	0.68	0.96	0.51	0.76	0.92
% Pred. FVC	98.93	108.32	109.18	99.47	94.82	92.87	95.45
	13.78	11.73	8.16	13.81	9.86	13.00	14.65
FEV_1 (L)	3.56	4.50	4.42	3.66	3.29	3.03	3.07
	0.85	0.62	0.74	0.80	0.42	0.47	0.74
% Pred FEV_1	93.10	107.42	108.64	92.42	92.47	85.65	84.97
	15.96	14.16	12.82	15.53	9.36	11.32	15.20
FEV_1/FVC (%)	75.67	81.53	81.09	75.14	77.76	73.26	71.74
	8.32	4.39	7.61	8.43	5.03	6.76	9.74
PEFR (L/sec)	8.45	10.23	8.47	8.02	8.10	8.64	7.87
	2.07	1.65	2.41	2.14	1.95	1.55	2.02

% Pred PEFR	92.65	108.11	89.09	86.14	91.88	97.65	88.45
	22.53	20.59	22.18	22.77	23.44	16.87	23.13
FEF_{25-75} (L/sec)	3.15	4.60	4.50	3.34	3.04	2.16	2.34
	1.43	0.95	1.46	1.35	1.00	0.87	1.25
% Pred FEF_{25-75}	65.91	89.84	89.91	67.58	68.00	49.17	51.10
	27.41	20.16	27.69	25.84	20.54	20.45	24.05

FVC: forced vital capacity
% Pred. FVC: % predicted forced vital capacity
FEV_1: forced expiratory volume in 1 second
% Pred. FEV_1: % predicted forced expiratory volume in 1 second
PEFR: peak expiratory flow rate
% Pred. PEFR: % predicted peak expiratory flow rate
FEF_{25-75}: mid-portion forced expiratory flow

These abbreviations will be used in the subsequent tables.

Table 2. Coefficients of Correlation Among Pulmonary Function Measurements in 135 Male Asbestos Workers.

	Age (years)	Exposure (years)	Smoking (P/day-yr)	FVC (L)	FEV_1 (L)	FEV_1/FVC (%)	PEFR (L/sec)	FEF_{25-75} (L/sec)
Age (years)	1.000	0.866	0.529	−0.680	−0.733	−0.324	0.299	−0.620
Exposure (years)		1.000	0.401	−0.615	−0.643	−0.222	−0.178	−0.542
Smoking (Packs/day-year)			1.000	−0.336	−0.487	−0.444	−0.250	−0.537
FVC (L)				1.000	0.885	0.067	0.376	0.534
FEV_1 (L)					1.000	0.515	0.487	0.829
FEV_1/FVC (%)						1.000	0.350	0.802
PEFR (L/sec)							1.000	0.354
FEF_{25-75} (L/sec)								1.000

Table 3. Multiple Regression Equations Relating Pulmonary Function Parameters to Age, Smoking Habit, and Asbestos Exposure for all Asbestos Workers.

Parameter	Equation	Correlation Coefficient	Std Error of the Estimate
FVC (L)	$y = -0.046A + 0.001P - 0.009W + 6.822$	0.682	0.702
FEV_1 (L)	$y = 0.041A + 0.006P - 0.005W + 5.542$	0.743	0.578
FEV_1/FVC (%)	$y = -0.171A - 0.139P + 0.113W + 83.756$	0.462	7.461
PEFR (L/sec)	$y = -0.084A - 0.010P + 0.057W + 11.092$	0.350	1.963
FEF_{25-75} (L/sec)	$y = -0.046A - 0.019P - 0.011W + 5.735$	0.663	1.096

A: Age of worker in years
P: Smoking habit in packs/day-year
W: Asbestos exposure in years

Table 4. Multiple Regression Equations Relating Pulmonary Function Parameters to Age and Asbestos Exposure for Nonsmokers.

Parameter	Equation	Correlation Coefficient	Std Error of the Estimate
FVC (L)	$y = 0.006A - 0.067W + 5.937$	0.816	0.539
FEV_1 (L)	$y = 0.008A - 0.064W + 4.817$	0.838	0.455
FEV_1/FVC (%)	$y = 0.030A - 0.173W + 81.842$	0.348	4.837
PEFR (L/sec)	$y = 0.047A - 0.128W + 9.788$	0.478	1.876
FEF_{25-75} (L/sec)	$y = 0.028A - 0.097W + 4.595$	0.697	0.940

A: Age of worker in years
W: Asbestos exposure in years

Table 5. Multiple Regression Equations Relating Pulmonary Function Parameters to Age, Smoking Habit, and Asbestos Exposure for Ex-smokers.

Parameter	Equation	Correlation Coefficient	Std Error of the Estimate
FVC (L)	$y = -0.069A + 0.005P + 0.005W + 7.566$	0.772	0.629
FEV_1 (L)	$y = -0.035A - 0.005P - 0.022W + 5.748$	0.826	0.511
FEV_1/FVC (%)	$y = -0.352A - 0.164P + 0.082W + 74.579$	0.517	7.060
PEFR (L/sec)	$y = -0.105A - 0.014P + 0.082W + 11.152$	0.265	1.859
FEF_{25-75} (L/sec)	$y = -0.016A - 0.024P + 0.082W + 4.759$	0.705	1.149

A: Age of worker in years
P: Smoking habit in packs/day-year
W: Asbestos exposure in years

Table 6. Multiple Regression Equations Relating Pulmonary Function Parameters to Age, Smoking Habit, and Asbestos Exposure to Smokers.

Parameter	Equation	Correlation Coefficient	Std Error of the Estimate
FVC (L)	$y = -0.053A + 0.008P - 0.008W + 6.776$	0.592	0.801
FEV_1 (L)	$y = -0.052A - 0.002P - 0.005W + 5.471$	0.673	0.623
FEV_1/FVC (%)	$y = -0.310A - 0.109P + 0.313W + 84.229$	0.398	8.633
PEFR (L/sec)	$y = -0.091A - 0.008P + 0.077W + 10.624$	0.366	1.976
FEF_{25-75} (/sec)	$y = -0.072A - 0.013P + 0.026W + 5.878$	0.625	1.113

A: Age of worker in years
P: Smoking habit in packs/day-year
W: Asbestos exposure in years

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NOTES ON THE SMITHSONIAN INSTITUTION'S CHIPPED STONE COLLECTIONS FROM UNION COUNTY, ILLINOIS

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This information was collected in August 1982 while examining the Union county, Illinois collections in search of evidence of Middle Archaic utilization of the aboriginal quarry sites located in Union county. Although no Middle Archaic material was found, the Smithsonian Institution's collection of lithic debris from this county is quite remarkable, and could form the nucleus of an intensive/extensive study both of aboriginal stone tool manufacture and patterns of prehistoric chert utilization in the eastern U.S.

There are three major chert types found in the western portion of Union county which were intensively utilized during the prehistoric period. They are Mill Creek, Kaolin, and Cobden cherts.

Mill Creek is perhaps the best known of these cherts. This chert occurs in lenticular nodules as well as in bedded formation. The cortex of the nodular forms is rough and weathered, and the color of the matrix can be blue, beige, grey, yellow, pink, or reddish brown. It was quarried prehistorically at various locations near the town of Mill Creek (Thomas 1894; Holmes 1919; Phillips 1900). Exposures of this lenticular nodular chert have been noted at several places on Mill Creek and Lingle Creek (Phillips 1900) and along the ridgetops and in the headwaters of tributaries of Cooper, Lingle, and Mill creeks in Union and Alexander counties (May 1980). Chert from these source areas was used in the production of bifacially flaked hoes that were widely traded during the Late Woodland-Mississippian period. Spielbauer (1976) provides an excellent summary of the literature pertaining to the workshop sites within this area, and May (1977) gives detailed information about the occurence of these workshops.

Kaolin chert is found in the Clear Creek drainage west of Cobden, near the town of Kaolin, Illinois (Spielbauer 1976), and along the ridges and slopes of Iron

Mountain (May 1980). This high quality chalcedonous-like chert occurs in lenses, large discoidal nodules, and as gravel in Clear Creek (May 1980). Kaolin chert has a medium grained matrix of variable translucency which has been described as transparent grains suspended in an opaque matrix. It occurs in a wide range of colors including white, tan, yellow, pink, brown, orange, and red.

Cobden chert is an exceptionally high quality, smooth grained, dense material which ranges from blue to grey to black; there is also a tan variety. This nodular chert has a distinctive coarse grained, but smooth cortex. A commonly noted diagnostic attribute is a concentric ring pattern in the matrix of the chert. The nodules outcrop at several points along the ridge at the head of Clear Creek, southwest of Cobden, Illinois, as well as in the gullies and ravines that feed into Clear Creek (Fowke 1928). It has also been noted downstream of Big Creek, near Dongola (May 1977).

The major chert type represented within Smithsonian holdings for Union county is Mill Creek chert. Most of this material is a single collection gathered by W.H. Holmes (cat. no. 208099-2114a). This collection is illustrated in B.A.E. Bulletin 60 (Holmes 1919:189-194).

The collection consists of unshaped chert nodules, hamerstones, and roughly 50 large hoe blanks. These artifacts are generally production failures/rejects and represent a variety of stages in the manufacturing trajectory of traditional Mississippian digging tools. This collection of production rejects is a rich source of information about the manufacturing techniques involved in the production of classic Mississippian hoes.

It is interesting to note that there are no finished artifacts of this type in this collection, nor in any of the Union county collections, to the best of my knowledge. However, there are some bifacially chipped side-notched hoes, artifacts which are technologically distinct from the hoe forms which form the majority of the Holmes collection. The collector for these bifacial side-notched hoes was not noted during my examination of the collections. They may or may not be part of the Holmes collection. This information can be found in the catalogue and/or accession files.

A very interesting part of the Holmes collection is a set of about 15 finely made Mill Creek preforms very similar to those generally described for late Archaic traditions. These preforms are approximately 110 mm in length, 50 mm wide, and are finely shaped and thinned into a standarized form. They are all rectangular with straight basal edges and a triangularly shaped distal section. They were not examined for edgewear, but did not appear to have been used.

A separate collection of artifacts from an aboriginal workshop in Union County was made by E. Palmer. These artifacts (cat. no. 71650-63) are also manufacturing rejects related to the production of Mill Creek hoes.

Unfortunately, there did not appear to be any Mill Creek debitage (chipping debris) in either of these collections.

Although there are no finished standard Mississippian hoes in the Union county collections, such hoes are found scattered throughout the museum's holdings. Time constraints prevented the recording of these catalogue numbers. However, it can be noted that there exists an interesting sample of hoes collected by Gerard Fowke which are made from what he calls "micaceous schist". These hoes are from the Alexander Mound, Lawrence county, Alabama, near Town Creek.

Fowke conducted research in this area in 1893-94(B.A.E. 15, p. XXXIV) which resulted in two separate collections. The first is catalogued from 32698 to 327043, and the second is catalogued 327226-279. The latter collection contains the micaceous schist hoes. Fowke reported this research in B.A.E. Bulletin 44, Archaeological Investigations II (1928).

The second Union county chert discussed here is Kaolin chert. This chert is most certainly the material referred to as novaculite by Fowke (1928:530-532). The Museum possesses a very small amount of this material, and it seems to be limited to a collection made by G. Fowke (cat. no. 233401-05). The materials consist of large flakes, a few preforms, and what appear to be Mississippian hoe blanks. Although the quantity of this material is limited, it is high quality, classic Kaolin chert.

The third Union county chert discussed here is Cobden chert. Several different collections were made of this chert and a variety of chipped stone technologies are represented. These include standard bifacial production, blade/ core manufacture, and bifacial discs probably manufactured in the Levallois like manner described by McNerney (1975) for Cobden manufacturing techniques. These holdings are not extremely large, but are remarkable for the technological variety represented.

The materials collected by G. Fowke (233401-05) consist of a large crudely made blade core which is roughly conical in shape, and large crude bifacial preforms which are not disc blanks. There is a finely made, standard pyramidal blade core, apparently collected by Holmes (208114). This core has a single prepared platform, with a series of blade scars indicating a standardized pattern of removal. This core, made from nodular chert, seems to be shaped on one large, very thick flake whose detachment resulted in a suitable core form with the ventral surface serving as the platform for blade removal.

Artifacts of this chert type were also collected by Whepley. His collection consists of several large flakes (279198-99). Technological analysis of these flakes would suggest the type of industry with which they would be associated; however, they were not closely examined at this time.

There is a very nice collection (n = 8) of large Cobden discs obtained by T.M. Perrine from Anna, Illinois (Union county). These large artifacts are all roughly oval and exhibit the distinctive ring pattern associated with Cobden chert. The larger of these discs weighed over 1400 grams. Several of them (including the largest) exhibit a striking platform indicating that they are actually huge flakes. These flakes are not faceted and are cortex covered. It is suggested that these discs were manufactured in the distinctive Levallois-like fashion described by McNerney (1975). The striking feature about this set of artifacts is the fact that all of them exhibit intensive use-wear along the entire margin. The edges are very smooth; some nibbling/ chipping was also observed. These edges were not examined under a microscope, so further information is not available.

During this cursory persual of the Illinois material, attention was paid to the presence of bifacially chipped discs which are assumed to be related to the Middle Woodland tradition in the eastern U.S. The Perrine collection is one such example. Other artifacts, also made from what appears to be Cobden chert are scattered throughout the collection. These discs were not searched for in any systematic manner, and only a few Illinos county collections were examined.

However, this list should aid future researchers looking for Illinois hornstone discs.

Beardstown (Cass county) cat. no. 138984; 15333
French Lick cat. no. 32360
La Salle county cat. no. 32360
St. Clair county cat. no. 138457
cat. no. 15350;27940 (county not recorded by myself)
1 disc in Jefferson county drawer
1 disc in White county drawer
(cat. no. not recorded by myself)

It is pertinent to note that most of these counties are considerably north of Union county, and are located in the lower and central Illinois Valley. This area was the focus of the Illinois Hopewell tradition.

The Smithsonian Institution also has a small collection of chipped stone from Wyandotte Cave, Harrison county, Indiana. The chert from this area is visually very similar to Cobden chert, and both of these high quality hornstone cherts were intensively exploited during the Middle Woodland period. It is assumed that Cobden chert was the source for the Illinois Hopewell tradition, and the chert from the southern Indiana area formed the primary source for the Ohio Hopewell. Fowke described a major workshop area at Wyandotte Cave, and notes that the chert from this county is certainly the source of the discs found at the Hopewell mounds in Chillicothe, Ohio (Fowke 1928:529).

The Wyandotte Cave collection consists of some debitage, production failures for small tools (ie., no large preforms), and some stemmed bifaces which appear to be late Archaic in temporal affiliation.

In addition there are two large ovate shaped bifaces, made from material which resembles the Harrison county/Cobden chert. These artifacts are from Owen county (cat no. 60728-9). Similar material was used for the manufacture of a small, finely made ovate biface which has a "cache blade" appearance, a projectile point, and another preform, all from Sullivan county, Indiana.

This list of the Smithsonian Institution's chipped stone collections from Illinois and Indiana is quite selective. It is by no means offered as a comprehensive inventory; although the information for Union county is fairly complete with regard to the chipped stone materials stored in the Union county drawers. The recording of the bifacial discs from Illinois is quite casual, as is the material listed for Indiana. In the latter instance, only artifacts made from possible Harrison county/Cobden chert were recorded. This lack of thoroughness is due to the fact that these materials were not the major focus of the examination of the Museum collections. However, this information is presented here to describe some of the Smithsonian Institution's chipped stone collections as they relate to chert source areas.

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CAPILLARIA AEROPHILA (CREPLIN, 1839) TRAVASSOS, 1915 (NEMATODA:TRICHUROIDEA) IN RED AND GRAY FOXES OF SOUTHERN ILLINOIS.

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ABSTRACT

Capillaria aerophila was observed in the mucosa of the trachea and bronchi of 51 (31%) of 165 red foxes (*Vulpes vulpes*) from Union, Jackson, and Williamson Counties between November, 1960 and February, 1964 and in the mucosa of the trachea and bronchi of 60 (11%) of 543 gray foxes (*Urocyon cinereoargenteus*) from Jackson, Johnson, Union and Williamson Counties in southern Illinois between November, 1959 and November, 1963. The prevalence of *C. aerophila* in *V. vulpes* from southern Illinois is similar to that reported from red foxes in most geographical localities of the contiguous United States. The magnitude of specimens of *U. cinereoargenteus* examined for *C. aerophila* in other studies allowed little basis for comparative evaluation. It was conlcuded that while *V. vulpes* constitutes an important reservoir host for *C. aerophila* in southern Illinois, *U. cinereoargenteus* is probably an incidental host and does not represent a serious threat as a source of this lungworm for other animals.

INTRODUCTION

The distribution, host specificity and life cycles of wildlife parasites have been emphasized as important factors in determining guidelines for wildlife management programs (LaRue, 1933; Swales, 1933; Allen, 1934; Van Cleave, 1937). Wild animals with high population densities and wide geographic distributions may

distribute their parasites to numerous habitats and other species of animals. The importance of such hosts in the epizootiology of diseases of wildlife species as well as certain zoonoses of humans and domestic animals has resulted in increasing interest in their parasites by mammalogists, parasitologists, wildlife researchers, veterinarians and clinicians.

Because of omnivorous tendencies, the red fox (*Vulpes vulpes* L.) and the gray fox (*Urocyon cinereoargenteus* (Schreber)) are exposed to a wide variety of parasites and as such consititute important reservoirs for parasites which may be transmitted to other wild carnivores, domestic animals and human beings. When considering the importance and value of red and gray foxes as wildlife entities, data concerning parasitism is pertinent to understanding their ecology.

Due to the paucity of information on the prevalence of the fox lungworm, *Capillaria aerophila* (Creplin, 1839) Travassos, 1915 (syns., *Trichosomum aerophilum* Creplin, 1839, *Eucoleus aerophilum* (Creplin, 1839) Dujardin, 1845, *Capillaria (Thominx) aerophila* (Creplin, 1839) Travassos, 1915) in *V. vulpes* and *U. cinereoargenteus* in Illinois, a four year survey was conducted in which 708 wild foxes were examined. This report not only constitutes the most extensive survey of red and gray foxes for *C. aerophila* in southern Illinois but the most extensive and third most extensive survey of this nematode with reference to gray and red foxes, respectively, in the contiguous United States.

MATERIALS AND METHODS

One hundred and sixty-five red foxes were either shot or trapped in Jackson, Williamson, and Union Counties, southern Illinois between November, 1960 and February, 1964. Likewise, 543 gray foxes were similarly taken in Johnson, Jackson, Williamson, and Union Counties between November, 1959 and November, 1963.

Necropsies were performed either soon after death or the carcasses were frozen for examination at a later date. The nasal sinuses, laryngeal region, trachea, and bronchi were scrutinized for nematodes and the lung tissue pressed between glass plates for examination under a dissecting microscope.

All nemotodes were washed in fresh saline. Live material was fixed in hot 70% ethanol and stored in 70% ethanol containing 5% glycerin. Dead nematodes were fixed and stored in a 5% glycerin-ethanol solution. Specimens were cleared by standard glycerin dehydration techniques. All nematodes were temporarily mounted in pure glycerin and studied by light and phase contrast microscopy.

RESULTS

Of the 543 *U. cinereoargenteus* collected from four counties over a period of 48 months, *Capillaria aerophila* was observed in the mucosa of the trachea and brochi of 60 (11%) animals, while 51 (31%) of 165 *V. vulpes* collected from three counties over a period of 40 months were infected. Because foxes were collected at intervals and not systematically by months over a period of several consecutive years, there are insufficient data to form any convincing conclusions on the seasonal dynamics of *C. aerophila*.

DISCUSSION

The literature is very sparce on reports of *Capillaria aerophila* in wild foxes of the contiguous United States. Further, comprehensive surveys of this lungworm in wild foxes are indeed few, allowing little basis for comparative evaluation. Buechner (1944) found 1 of 11 gray foxes from Texas infected with this helminth. Goble and Cook (1941) reported *C. aerophila* in the trachea and lower bronchi of 22 (55%) of 40 *Vulpes vulpes* from Albany and Greene counties, New York. The following year, Goble and Cook (1942) reported *C. aerophila* in 66 (35%) of 190 red foxes and 6 (7%) of 89 gray foxes from Albany, Greene and Washington Counties, New York. Zeh et al. (1977) detected *C. aerophila* in 87 (41%) of 211 red foxes and 25 (28%) of 89 gray foxes taken in five eastern and several central counties of New York.

The prevalence of *C. aerophila* in *Vulpes vulpes* from southern Illinos is similar to that reported in this host from most geographical localities. The magnitude of specimens of *Urocyon cinereoargenteus* examined in the present study constitutes the most extensive survey for *C. aerophila* in gray foxes in the contiguous United States. Examinations of larger host populations from other geographical localities are needed for comparative evaluation. The finding of 11% of *Urocyon cinereoargenteus* infected with *C. aerophila* in the present study is slightly higher than that reported by Goble and Cook (1942). The report of a 28% prevalence of this lungworm in gray foxes from five eastern and several central counties of New York (Zeh et al., 1977) is high compared to either Goble and Cook's report (1942) or to the present study. However, this may be due to differences is a variety of ecological factors, namely, host population densities, age of the host, climatic conditions, season, length of the study period, and accessibility of paratenic hosts.

Life cycle studies reported by Christenson (1938) reveal that eggs of *C. aerophila* are either coughed out or swallowed and passed out with the feces. They develop to the infective stage in 5 to 7 weeks, and remain viable for over a year. Eggs survived the winter in Minnesota when the temperature was as low as -26°C. Infection results following ingestion of eggs which hatching in the intestine and the larvae migrate to the lungs presumably by way of the circulatory system. Here they develop further and reach maturity approximately 40 days post infection. Borovkova (1949) reported that earthworms, *Lumbricus* and *Allolobophora* can serve as transport hosts. Thus, foxes may become infected with *C. aerophila* by ingesting either viabie eggs or possibly be ingesting earth worms containing viable larvae.

The life cycle and prevalence of infection of *C. aerophila* in *V. vulpes* suggests that this wild carnivore constitutes an important reservoir host for this lungworm in other wild animals and domestic animals as well. However, the low prevalence of *C. aerophila* in *U. cinereoargenteus* reported in the present study suggests that the gray fox is probably an incidental host and does not represent a serious threat as a source of *C. aerophila* for other animals in southern Illinois. Further studies are warrented to update this data and to determine whether gray foxes have a role in the epizootiology of *C. aerophila* infections in this area.

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WATER QUALITY AND WATERSHED LAND USES OF JOHNSON SAUK TRAIL LAKE

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ABSTRACT

A study of Johnson Sauk Trail Lake, Henry County, was conducted in 1981 to delineate existing lake conditions, to examine causes of degradation, if any, and to identify and quantify the sources of nutrients and any pollutants flowing into the lake. The lake watershed, in general, is in excellent condidtion with excellent ground cover and very little land disturbance. The lake water quality characteristics were found to be typical of midwestern lakes, with high alkalinity, conductivity, and dissolved solids. There was an abundance of phosphorus in the lake system all the time. The main lake tributaries were not found to convey unusual amounts of suspended sediment loads. Fish flesh analyses revealed levels of pesticides, heavy metals, and organochemicals either below detectable limits or below regulatory limits. A number of water quality impairments were found to persist in the lake, including hypolimnetic oxygen depletion during summer months, algal blooms, and dense macrophyte growths in the littoral zone. Internal regeneration of nutrients was identified as the major source of nutrients to the lake. The lake is eutrophic by all the measures and indices suggested in the literature.

INTRODUCTION

Johnson Sauk Trail Lake is located in Henry County. It is a 57.4-acre lake with a maximum depth of 23 feet. The lake was formed in 1956 by the impoundment of King Creek. This publicly owned lake and the surrounding park area managed by the Illinois Department of Conservation for outdoor recreational activities. These include bank fishing, boat fishing, ice fishing in season, boating, canoeing, camping, picnicing, hiking, and winter sports. Hunting in season for cock pheasants, quails, rabbits, doves, and squirrels, as well as bow hunting for deer, are permitted in the state park. The location and watershed boundary for

the lake are shown in Figure 1; other relevant general information is included in Table 1.

The park offers free interpretive programs during summer months from June through August. Nature study and cultural and historical aspects of the region are taught through tours, nature walks, craft workshops, and camp fire events. Approximately 8 miles of extensive foot trails exist in the park for visitors' use. There is no fee charged to the general public for the use of the state park facilities except for camping fees and annual state fishing and hunting license fees.

The lake is stocked and managed by the Fisheries Division of the Department of Conservation for warm water fish such as largemouth bass, bluegill, redear, sunfish, and catfish. Public access to the lake exists. A ramp and docks for private and rental boats are provided on the northwest shore. Boats other than those that are manually propelled are limited to electric-powered motors. Swimming is prohibited.

LAND USES

The watershed area for the lake is approximately 876 acres, and about 94 percent of it is now in state ownership. Detailed information on the land uses in the watershed and the changes which occurred between the years 1970 and 1979 is shown in Table 2. The land use information was extracted from aerial photographs taken in 1970 and 1979 by the Soil Conservation Service of the U.S. Department of Agriculture.

A significant shift in land use within the watershed occurred between 1970 and 1979. Cropland decreased form 36.9 to 6.2 percent. Pasture and grassland increased from 17.5 to 40.2 percent. There was a slight increase in woodland from 318 to 352 acres. Native oak and pine plantings surround the lake. The apparent increase in water surface area in 1979 over that in 1970 is probably due to the low lake water level in 1970 when the aerial photographs were taken.

The watershed, in general, is in excellent condition with excellent ground cover and very little land disturbance. All the five privately held land parcels lie on the outer fringes of the watershed. These land parcels are kept partly in permanent pastures and partly in cultivation. Two landowners raise a small number of dairy cattle and beef stock. Except for the wildlife food plots, there is no land disturbance activity within the state-owned portion of the watershed. The food plots, about 28 acres, are plowed and seeded with corn, sunflower, and millet by park officials, mainly to provide food and habitat for wild animals and birds. However, these food plots lie within a sodded boundary.

For estimating the soil loss rate from the watershed, the boundaries of land uses were first transposed on the watershed soil map. Fifteen categories of soil types, slopes, and erodibility potentials were identified. The soil types and their associated land uses within each subwatershed were then delineated with the aid of a digitizer. The soil loss rates were computed through use of the Universal Soil Loss Equation, or USLE (Wischmeier and Smith, 1965):

$$A = RKSLCP$$

In this equation A is the average annual soil loss rate in tons per acre per year, R is the rainfall factor, K is the soil erodibility factor, S is the steepness factor, L is the slope length factor, C is the cropping factor, and P is the support practice factor.

The slope, slope length, and cropping factors were determined for various

land uses in consultation with the Henry County District Conservationist. The erodibility factor of each soil type was obtained from soil description files available from the Soil Conservation Service State Office at Champaign. The R × P factor value was assigned as 135 for agricultural cropland and 180 for all other land uses. Based on the soil information compiled in the watershed, the soil loss rates were computed. The total soil loss for each soil type was obtained by multiplying the rate and the soil acreage. The estimated soil losses are shown in Table 3.

The total amount of soil loss in the watershed was estimated as 599.8 tons/year. Excluding the lake area, the mean soil erosion rate for the watershed is estimated as 0.73 tons/acre/year.

LIMNOLOGICAL ASSESSMENT OF THE LAKE

In order to assess the current conditions of the lake, certain physical, chemical, and biological characteristics of the lake were monitored during the 1981 calendar year. The lake was monitored on a once-a-month basis during January through April and again from October through December, and it was visited on a biweekly schedule during the intervening summer months. A total of 17 visits were made during the year. During each of these visits water samples were collected from King Creek upstream and downstream of the lake for chemical and biological characterization. The locations of the lake and tributary monitoring stations are shown in Figure 1.

In-situ observations for temperature, dissolved oxygen, and secchi disc readings were made at the deep and shallow stations in the lake. Temperature and dissolved oxygen measurements were obtained in the water column, at 2-foot intervals for the deep station and at 1-foot intervals for the shallow station, commencing from the surface of the lake.

Water samples for chemical analyses were obtained from the lake with a Kemmerer sampler at points 1 foot below the surface, mid-depth, and 1 foot from the bottom. Integrated water samples within a depth twice the secchi disc readings were obtained for phytoplankton identification and enumeration, and chlorophyll-a determination. A Juday sampler was used for obtaining integrated samples. All the samples were stored on ice during transportation and kept in a refrigerator until processed, with the exception of the algae and chlorophyll-a samples. Chlorophyll-a samples were kept frozen.

Water subsamples in a volume of 380 ml were collected for algal identification and enumeration, preserved with 20 ml of formalin at the time of collection, and stored at room temperature until examined.

Determinations for pH, alkalinity, and conductivity were made at the lake site soon after sample collections. Laboratory analyses were performed to determine total suspended and dissolved solids, volatile suspended solids, turbidity, total and dissolved phosphorus, nitrate-nitrogen, total Kjeldahl-nitrogen, and chlorophyll-a. Streamwater samples were not examined for chlorophyll-a content. Composite fish flesh samples were analyzed for pesticides, organochemicals, and mercury. The methods and procedures involved in these determinations are given elsewhere (Kothandaraman and Evans, 1983).

A macrophyte survey of the lake was made in July from a boat with the

sevices of a scuba diver. Samples of submerged vegetation were obtained with roots intact. The macrophyte beds were probed thoroughly by the scuba diver, and representative samples of the various types of vegetation found in the lake were obtained and placed in plastic bags with lake water, which were then sealed. These samples were then examined with stereo microscope, and identified. The areal extent of the submerged vegetation was noted on the lake map.

Benthic samples for macroinvertebrate examination were obtained at monthly intervals during June through September. The bottom muds were also examined for percent moisture and volatile fraction. Benthic samples were obtained at both the deep and shallow stations in the lake.

Water Quality Characteristics

Physical Characteristics

Temperature and Dissolved Oxygen. Lakes in the temperate zone generally undergo seasonal variations in temperature through the water column. These variations, with their accompanying phenomena, are perhaps the most influential controlling factors within the lake.

Isothermal plots for the deep station in Johnson Sauk Trail Lake are shown in Figure 2. The vertical temperature profiles for the deep station on selected dates are shown in Figure 3. From Figure 2 it is seen that the summer stratification begins to set in during the latter half of May and intensifies progressively during the summer months. The maximum water temperature of 28.0°C was observed on July 7, 1981. The lake experienced the maximum temperature differential of 12.0°C between the surface and bottom waters on the same date. Thereafter, the intensity of stratification began to decrease. The lake was found to be uniform in temperature after the fall turnover on October 6, 1981.

The isopleths of dissolved oxygen for Johnson Sauk Trail Lake are shown in Figure 2. Selected vertical DO profiles for the deep station are shown in Figure 4. Dissolved oxygen depletion began to occur during the early part of May. As the summer thermal stagnation intensified, the anoxic zone of hypolimnetic waters increased progressively, reaching a maximum during mid-July. The extent of this anaerobic zone started diminishing thereafter, and the DO concentration became uniform in the water column in late September. As is apparent from Figure 2, the progression of this anoxic zone coincided with the progression of the thermal stratification in the lake.

During the period of peak stratification, the lake was totally anoxic at depths 8 feet from the surface and below. About 177 acre-feet or approximately 38 percent of the water volume of the lake was anoxic, severely restricting its habitat for desirable fish food organisms and fish. During summer months, adequate oxygen levels did not generally exist at depths below 10 feet from the surface.

Secchi Disc Transparencies. Secchi disc visibility is a measure of the lake water transparency or its ability to allow light transmission. The mean and range of values observed for secchi disc readings at the deep station are given in Table 4 along with the summary of observations for other physical and chemical water quality parameters. The temporal variations in secchi disc observations are shown in Figure 5. The mean secchi disc reading was 50 inches. A maximum value of 103 inches was observed in February when the lake had ice cover. The minimum of 6 inches occurred in April immediately after a heavy rainfall. About 5.69 inches of rainfall was recorded over a period of 7 days, with 3.33 inches occuring in one 24-hour period. The decrease in secchi disc readings in April was due mainly to

the influx of fine particulate matter into the lake after the prolonged and intense rainfall. Secchi disc readings during June, July, and August were in the range of 18 to 51 inches.

Turbidity. High turbidity affects aesthetic quality of the water. Temporal variations of turbidity in surface, mid-depth, and near bottom sampling points of the deep station are shown in Figures 5, 6, and 7, respectively. These values are summarized in Table 4. The turbidity of surface and mid-depth samples had relatively low mean values of 7.7 and 7.9 NTU, respectively, except for a single observation of 60.2 NTU on April 14, 1981. Lake turbidity at that time was nearly eight times as high as the normal values. This was caused by a significant influx of suspended sediments in to the lake after the heavy rainfall referred to earlier. Wet antecedent conditions prior to the heavy downpours created conditons conducive to soil erosion and sediment transport from the watershed. Turbidity of the near bottom water samples was relatively higher, due partly to the settling of particulate matter from the surface.

Chemical Characteristics

pH and Alkalinity. The pH and alkalinity values observed in Johnson Sauk Trail Lake are typical of Illinois lakes. The range of pH values was the highest for the surface waters (7.9-9.6) and the lowest for the near bottom waters (7.6-8.6). Also, alkalinity decreased in the surface water samples during summer months, presumably due to algal photosynthesis, and increased at the same time in the bottom water samples. Mean alkalinity values for the surface, mid-depth, and deep water samples were 157, 168, and 188 mg/1, respectively.

Conductivity. The mean conductivity values for the lake water samples were 281 μmho/cm for the surface, 291 μmho/cm for the mid-depth, and 312 μmho/cm for the near bottom. The increasing trend of conductivity toward the lake bottom follows the same pattern as for alkalinity. Conductivity of bottom waters was high during the summer months, indicating the increased mineralization of organic matter under anaerobic conditions. Lower conductivity values at the surface reflect biological uptake of dissolved minerals. The temporal variations of conductivity in the lake waters are shown in Figures 5, 6, and 7.

Phosphorus. A summary of the observations for total and dissolved phosphate-phosphorus in the lake is given in Table 4. Temporal variations in phosphorus content in the lake are depicted in Figures 5, 6, and 7. Even the lowest observed total phosphorus value was 3 or 4 times higher than the critical value of .01 mg/1 for inorganic phosphorus suggested by Sawyer (1952). The mean dissolve phosphorus levels in the lake varied from 0.07 mg/1 at the surface to 0.30 mg/1 near the bottom. Phosphorus level tended to increase in the lake after a heavy rainfall, and this phenomenon was most pronounced during the April 14, 1981, sampling which was preceded by a week-long heavy rainfall.

The total and dissolved phosphorus levels in the lake after the spring turnover were 0.09 and 0.02 mg/1, respectively. A significant and progressive increase in phosphorus content in the deep waters of the lake was noted during the summer months (Figure 7), until the onset of fall turnover. The highest total phosphorus level measured in the lake was 0.95 mg/1. This occurred in the near bottom waters on September 2, 1981.

The ratio of dissolved phosphorus to the total phosphorus in the surface water samples varied from 0.14 to 0.67 with a mean value of 0.35. The high values rang-

ing from 0.14 to 0.67 occurred during the months January through May when primary productivity was very low. During summer months, when the primary productivity in the lake was relatively high, the ratio varied from 0.17 to 0.50 with a mean of 0.29.

The dissolved phosphorus to total phosphorus ratio at mid-depth varied from 0.16 to 0.67 with a mean of 0.36 for the duration of the lake monitoring. Corresponding values for the deep station were 0.05 to 0.83, and 0.50. The mean values at these locations during the summer months were respectively 0.31 and 0.65. There was no biological uptake of dissolved phosphorus taking place at these locations where anoxic conditions prevailed during summer months. The high concentrations of dissolved and total phosphorus levels at mid-depth and deep stations during summer months were the result of mineralization of organic-rich bottom sediments under anaerobic condition.

Nitrogen. The mean and range of values fo ammonia-, nitrate-, and Kjeldahl-nitrogen in the lake are included in Table 4, and the temporal variations in these parameters are shown in Figures 5, 6, and 7. Mean total inorganic nitrogen (total ammonia-nitrogen and nitrate-nitrogen) was always higher than the suggested critical concentration (0.3 mg/1) for inorganic nitrogen (Sawyer, 1952). The mean values for total ammonia-nitrogen increased from 0.19 mg/1 at the surface to 1.03 mg/1 at the bottom. Nitrate-nitrogen mean values were 0.10 mg/1 at the surface, 0.10 mg/1 at mid-depth, and 0.12 mg/1 at the bottom. Kjeldahl-nitrogen mean values showed an increasing trend toward the bottom of the lake.

Significant decreases in nitrate-nitrogen concentrations were detected throughout the lake during summer months. Ammonia and Kjeldahl-nitrogen concentrations increased severalfold at the mid-depth and the deep sampling points during the summer thermal stagnation period. This is a clear indication of the intense anaerobic decomposition of the organic debris occurring on the lake bottom.

Total Solids, Total Dissolved Solids, and Suspended Solids. Dissolved solids concentrations found in Johnson Sauk Trail Lake are typical of midwestern lakes. Abnormally high suspended solids concentrations were found in the lake only for the April 14, 1981, sampling trip. As indicated earlier, this was due to a week-long heavy rainfall preceding the sampling date. On this particular occasion only, the suspended sediments were predominantly inorganic in nature for the surface and mid-depth samples. Otherwise, the major portion of the suspended sediments was organic (volatile) matter, indicating that transparency was influenced primarily by algae. High suspended sediment values reported for the lake near-bottom samples may be due partly to the accidental lake bottom disturbance while sampling with a Kemmerer sampler, and partly to the settling of particulate matter from the water column. The results for solids determinations are shown in Table 4 and in Figures 5, 6, and 7.

Biological Characteristics

Algae. The total algal counts and the species distribution of algae found in the lake are shown in Table 5. Chlorophyll-a content and algal biomass are also listed in the table. Except for the observations during May, algal counts in the lake were found to be of bloom proportions (500 cts/ml), with blue-green dominating. Blue-green algae create unsightly conditions in the lake by forming algal scum under quiescent lake conditions. Chlorophyll-a was found to peak on July 7, 1981, with a concentration of 80 μg/1. Algal biomass was found to be the highest on

September 1, 1981, with a concentration of 151.4 $mm^3/1$. Relatively large numbers of flagellates were found in the water sample on that date. These organisms are much larger than the other types of algae found in the lake, accounting for the very large biomass. There apparently is no correlation between biomass, chlorophyll-a, and the counts of algae found in Johnson Sauk Trail Lake.

Benthic Organisms. The types and densities of benthic macroinvertebrate communities in the lake sediments are given in Table 6. *Chaoborus* was the dominant species found in both the shallow and deep stations. The overall population density was higher in the deep station than in the shallow station at all times. This is probably due to the lack of fish predation in the hypolimnetic zone of the deep station, which was anoxic. Even though the number of Chironomidae found in the lake was relatively small compared to *Chaoborus*, Chironomidae constituted a sizeable portion of the biomass. Relatively large numbers of large-sized Chironomidae were found in the samples. The overall averages of the macroinvertebrate densities were 3140 and 6350 counts/m^2 for the shallow and deep stations, respectively. However, the benthic populaton in the shallow station was more diverse than that in the deep station. The average number of taxa per sampling was 3.80 in the shallow station versus 2.00 for the deep station.

Macrophytes. Aquatic vegetation is found in most lakes and is beneficial to the natural ecosystem. It provides food and cover for aquatic organisms, provides oxygen, and stabilizes bottom sediments. However, excessive vegetation generally interferes with recreational activities, adversely affects aquatic life, and destroys asthetic values to the extent of decreasing the economic values of properties surrounding a lake. Under these circumstances, aquatic plants are often referred to as weeds.

The areal extent and types of vegetation found in Johnson Sauk Trail Lake are shown in Figure 8. All the macrophytes found in the lake were the submergent type except for a very small patch of bulrush. The dominant types of vegetation in the lake were horned pondweed and coontail. The shallow upper end of the lake was dense with coontail, which thrived in the lake at depths of 8 feet and less. About 15.4 acres of the lake, constituting 26.8 percent of the lake water surface, was covered by a dense growth of macrophytes. This portion of the lake was unsuitable for fishing or boating. During June and July 1981 the shallow portion of the lake was partially treated with aquathol-K for macrophyte control.

Fish Flesh Analyses

Rule 302.210 of the Water Pollution Regulations of Illinois (1982) states that "any substance toxic to aquatic life shall not exceed one-tenth of the 96 hour median tolerance limit (96 hr TL_m) for native fish or essential food organisms." The primary concern in fish flesh analysis is in regard to the possibility of the bioaccumulation of toxic sutstances like mercury, organocholorine, and other organochemicals in fish which may prove detrimental to higher forms of life in the food chain, including humans, the ultimate consumers.

Composite samples of fish flesh were taken from five largemouth bass fish of the following sizes: 1.08 lbs, 1.08 lbs, 0.93 lbs, 0.91 lbs, and 0,89 lbs. A composite sample from five redear fish of sizes 0.51 lbs, 0.50 lbs, 0.48 lbs, and 0.42 lbs was also analyzed. In addition, two separate analyses were performed on whole carp of sizes 6.10 lbs and 1.49 lbs.

Concentrations of all the toxicants examined showed levels below detection limits. Chlordane, dieldren, DDE, DDD, aldrin, lindane, heptachlor epoxide, DDT, endrin, benzene hexachloride, mirex, and hexachlorobenzene all showed concentrations < 0.01 ppm. The concentration of methoxychlor was 0.05 ppm, and that of toxaphene was < 0.5 ppm. PCBs were < 0.1 ppm, and lipid content was 0.4 to 12.8 percent. Dieldrin concentrations in whole carp samples were 0.037 ppm for the 1.49-lb fish and 0.018 ppm for the 6.10-lb fish. Mercury levels in the carp samples were less than 0.03 ppm. They were 0.07 ppm in the redear fish samples and 0.33 ppm in the largemouth bass samples. The levels of pesticides and organochemicals found in the fish flesh samples are not cause for concern.

SUMMARY

Johnson Sauk Trail Lake, formed in 1956 by the damming of King Creek, is a 57.4-acre lake with a total watershed of about 876.1 acres. The lake and the surrounding park, which are publicly owned, are managed by the Department of Conservation for recreational purposes such as fishing, boating, camping, and hunting. The park system is open to the public throughout the year.

More than 90 percent of the watershed is in state ownership and the rest is in small private land holdings. Agriculture is a very minor land use in the watershed, constituting only 6.2 percent. Except for a few small tracts of land (28.2 acres; 3.2 percent of total) which are used as wildlife food plots, there is no activity within the state-owned portion of the watershed which involves land disturbance. There is no point source waste discharge within the watershed.

The lake has exhibited very high biological productivity since the early years of its formation, requiring algicide and herbicide applications to control algae and macrophytes. The lake experiences summer stratification. During the peak stratification period, the lake was found to be totally anoxic at depths below 8 feet from the surface. About 38 percent of the lake volume is devoid of oxygen at that time. Average summer secchi disc transparency was found to be about 3.2 feet.

The lake water quality characterisitcs were found to be typical of midwestern lakes with high alkalinity, conductivity, and dissolved solids. Mean phosphorus concentration in the lake during winter months was found to be 50 μg/1.

The three main tributarties to the lake were not found to convey unusual amounts of suspended sediment loads under normal rainfall conditions. Even tributary samples obtained immediately after storm events indicated values for turbidity and suspended sediments within the range of values observed for routine samples.

The lake exhibits a high biological productivity. Algal growths of bloom proportons were encountered during summer months, with blue-greens the dominant species. However, there was an abundance of phosphorus in the lake system all the time. About 15.4 acres of the lake was covered with dense growth of macrophytes. Coontail and pondweed were the dominant vegetation found in the lake.

The lake is eutrophic by all the measures and indices suggested in the literature. Even though the watershed has been returned to an undisturbed condition with permanent vegetative cover, such conditions as hypolimnetic oxygen depletion during summer months, algal blooms, dense macrophyte growths in the littoral zone, and other water quality impairments still persist. Internal regeneration of nutrients has been identified as the major source of nutrients to the lake.

The levels of pesticides, heavy metals, and organochemicals found in fish flesh samples were either below detectable limits or below regulatory limits.

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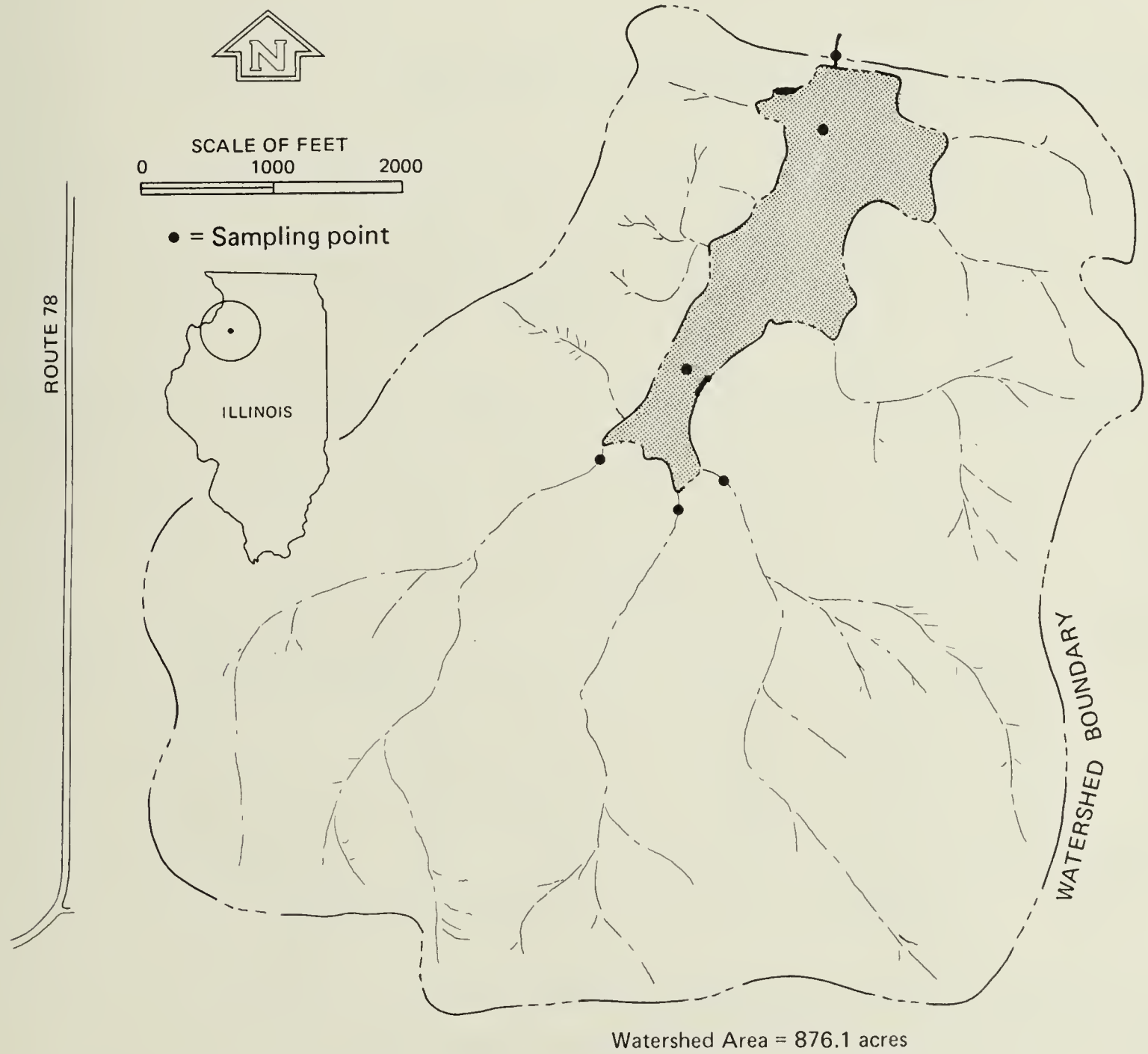

Figure 1. Location and watershed boundary, Johnson Sauk Trail Lake

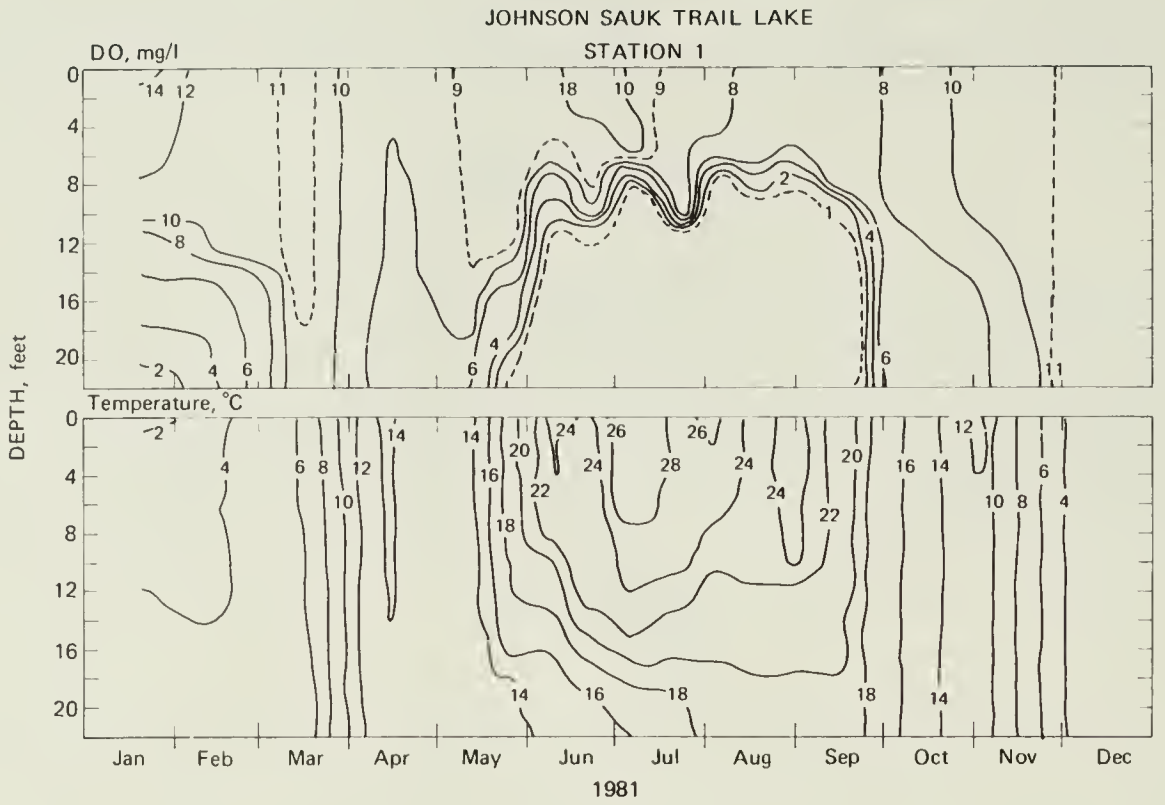

Figure 2. Isothermal and dissolved oxygen plots for the deep station

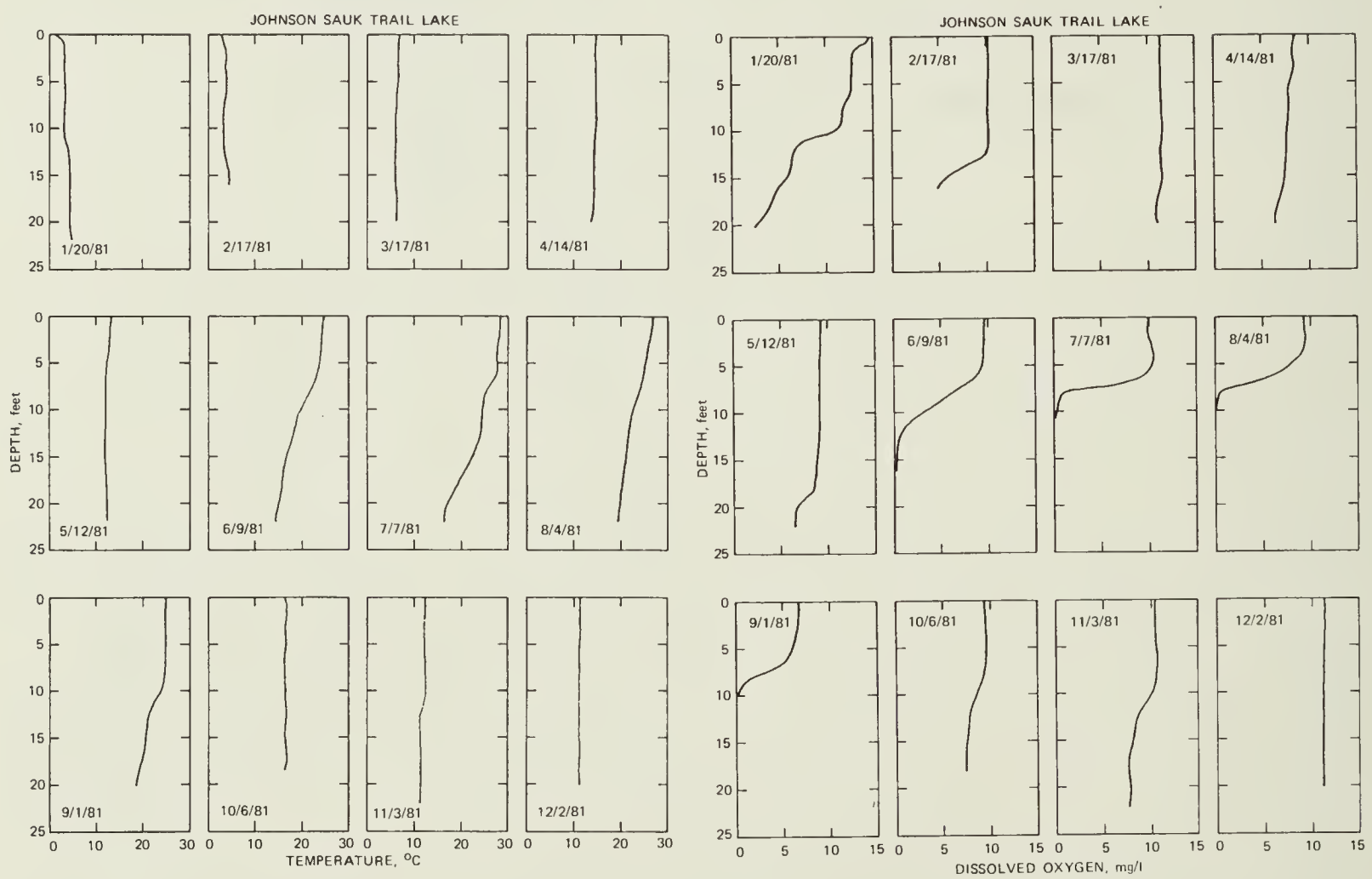

Figure 3. Temperature profiles at the deep station on selected dates

Figure 4. Dissolved oxygen profiles at the deep station on selected dates

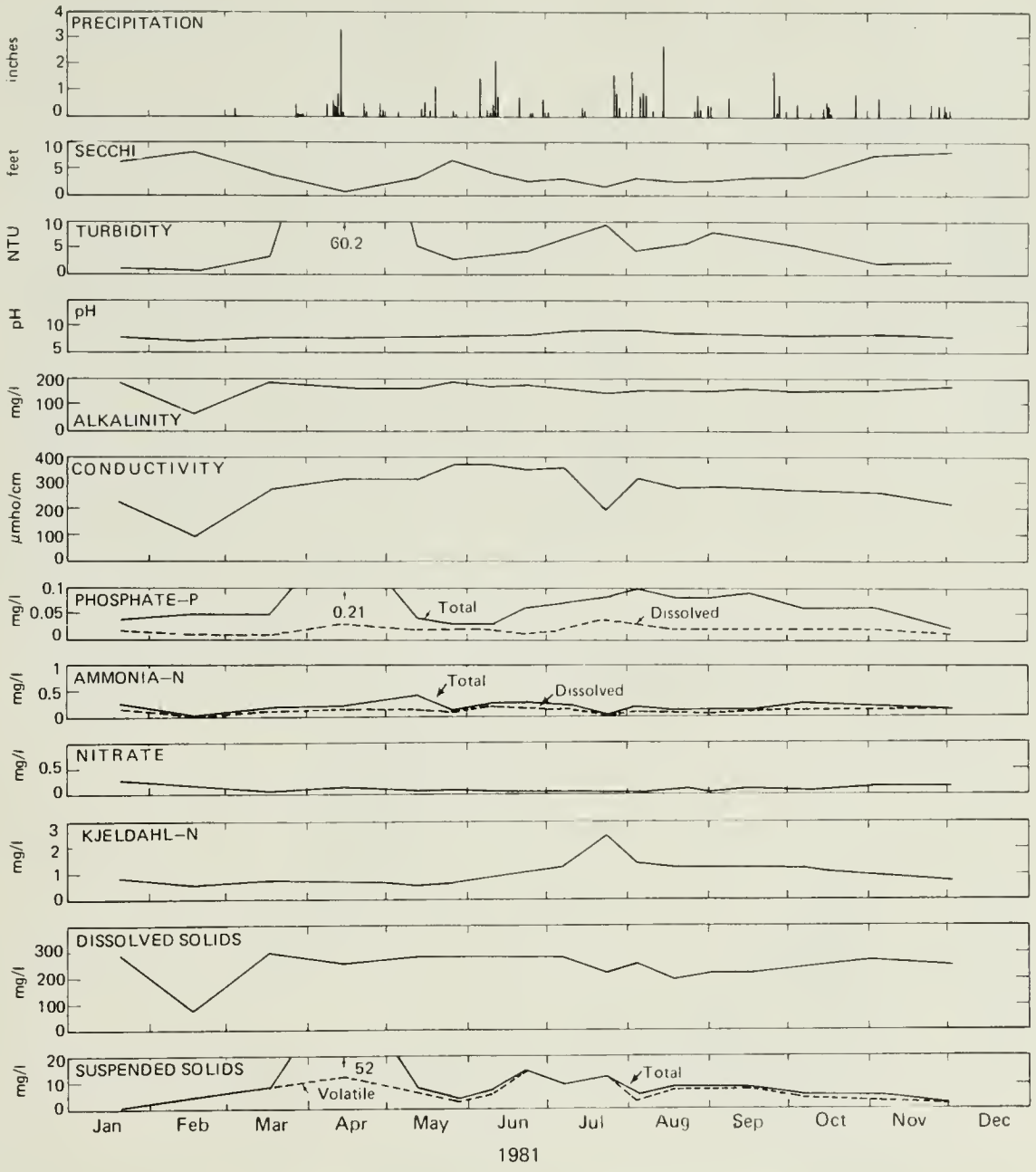

Figure 5. Temporal Variations in the near surface water quality characteristics at the deep station

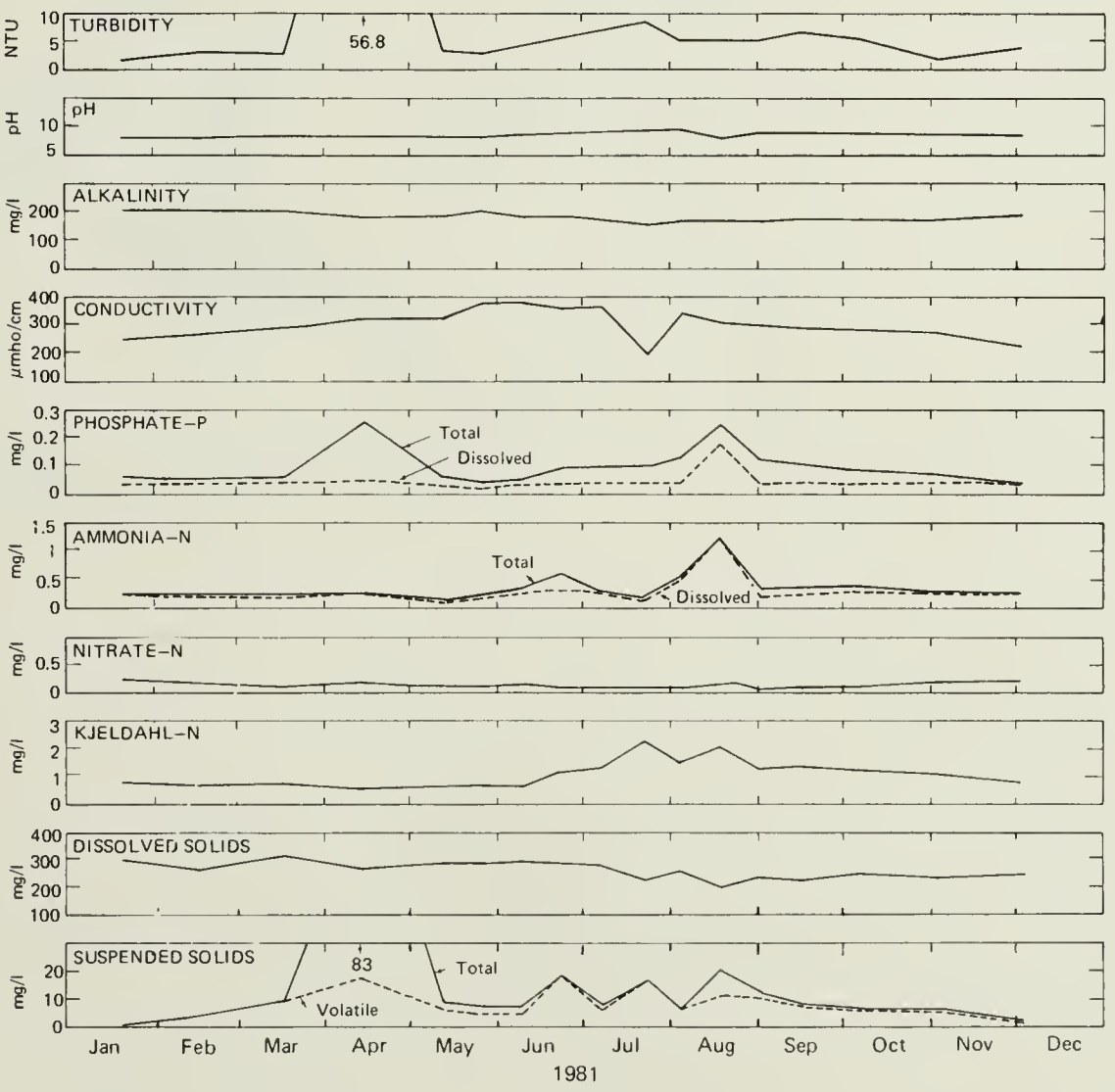

Figure 6. Temporal variations in mid-depth water quality characteristics at the deep station

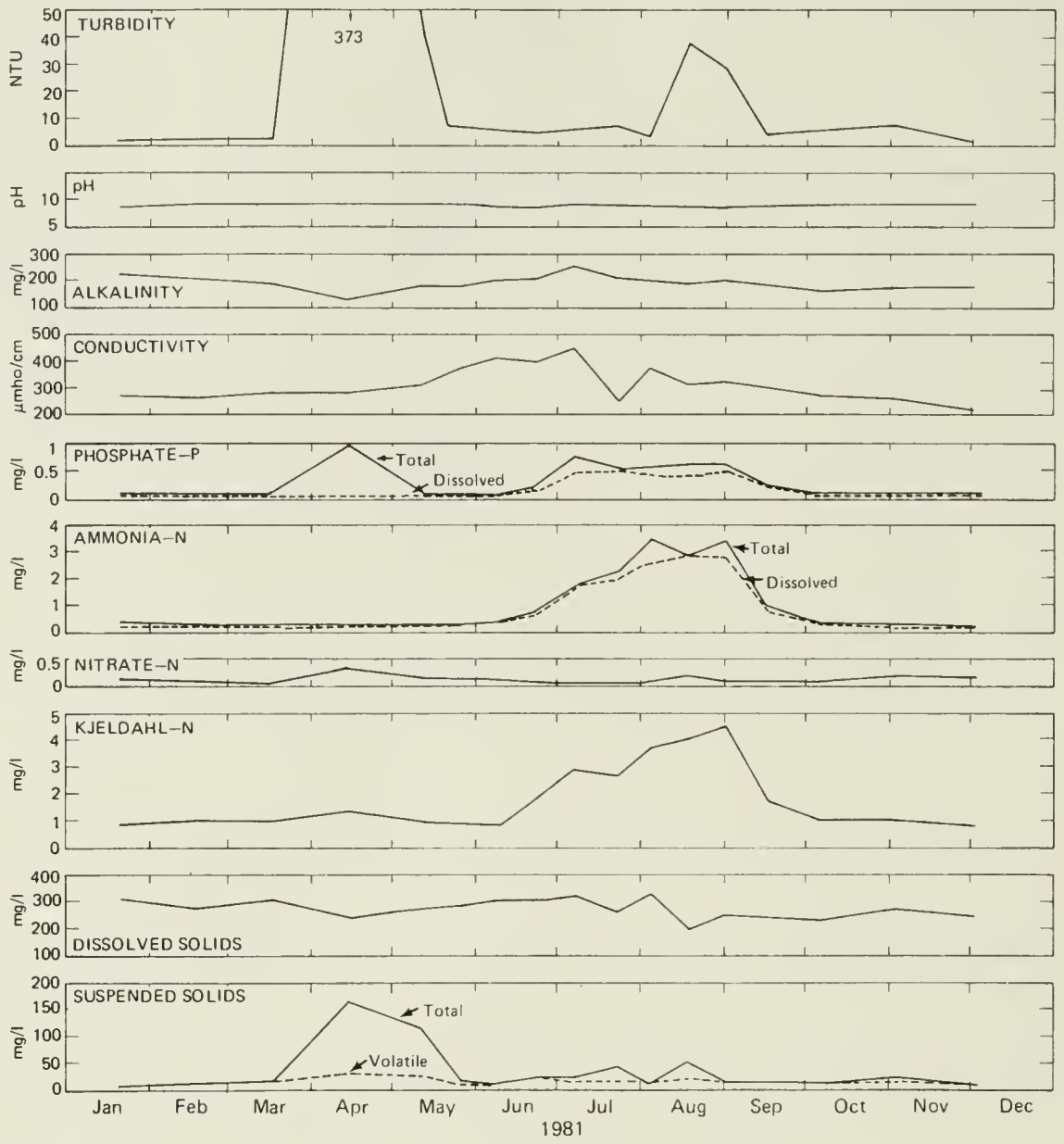

Figure 7. Temporal variations in near bottom water quality characteristics at the deep station

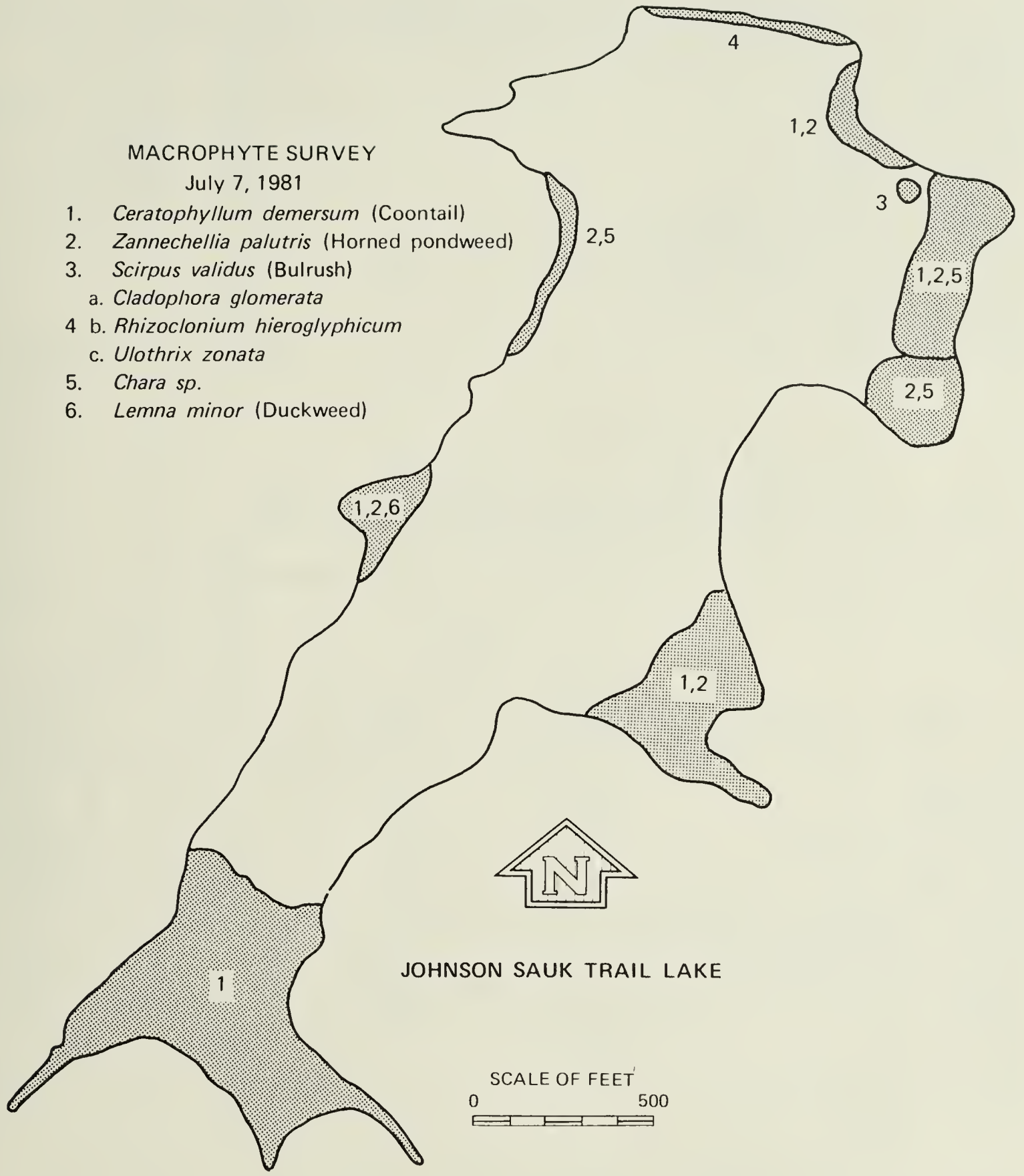

Figure 8. Types and areal extent of macrophytes

Table 1. Morphometric Details regarding Johnson Sauk Trail Lake

Surface area, acres	57.4	(23.2 ha)
Volume, acre-feet	471.5	($0.58 \times 10^6 m^3$)
Mean depth, feet	8.2	(2.50 m)
Maximum depth, feet	23.0	(7.01 m)
Length of shoreline, miles	1.5	(2.41 km)
Average retention time, years	1.96	
Total original capacity loss, percent	13.3	
Annual capacity loss, percent	0.58	
Watershed area, acres	876.1	($3.55 km^2$)

Table 2. Johnson Sauk Trail Lake Watershed Land Uses

	1970		1979	
Type of land use	Area (acres)	Percent of total	Area (acres)	Percent of total
Cropland	323.2	36.9	54.2	6.2
Pasture or grassland	153.1	17.5	351.9	40.2
Woodland	317.8	36.3	352.4	40.2
Recreational development	22.6	2.6	32.0	3.7
Wildlife food plots	0.0	0.0	28.2	3.2
Farmsteads	2.9	0.3	0.0	0.0
Water	56.4	6.4	57.4	6.6
Total	876.1		876.1	

Table 3. Soil Losses in Johnson Sauk Trail Lake Watershed
(Tons per year)

Land use	Total
Cropland	217.95
Grassland, food plots, recreational areas	367.98
Woodland	13.88
Total	599.81

Food plots provide food and habitat for wild animals and birds. Please see the text under LAND USES for explanation.

Table 4. Johnson Sauk Trail Lake Water Quality Characteristics

Parameter	Near surface Mean	Near surface Range	Mid-depth Mean	Mid-depth Range	Near bottom Mean	Near bottom Range
Secchi readings (inches)	50	6-103				
Turbidity (NTU)	7.7	0.4-60.2	7.9	1.4-56.8	35.1	1.6-377.0
pH (dimensionless)		7.9-9.6		8.1-9.5		7.6-8.6
Alkalinity	157	67-187	168	139-195	188	126-250
Conductivity (μ mho/cm)	281	98-371	291	185-370	312	214-445
Total phosphate-P	0.07	0.03-0.21	0.09	0.04-0.25	0.30	0.03-0.95
Dissolved phosphate-P	0.02	0.01-0.04	0.03	0.01-0.16	0.16	0.01-0.49
Total ammonia-N	0.19	0.03-0.42	0.30	0.12-1.16	1.03	0.17-3.41
Dissolved ammonia-N	0.13	0.02-0.21	0.25	0.05-1.15	0.87	0.12-2.72
Nitrate-N	0.10	0.03-0.27	0.10	0.03-0.17	0.12	0.05-0.34
Total Kjeldahl-N	1.01	0.52-2.39	1.10	0.57-2.25	1.76	0.75-4.36
Dissolved solids	242	72-296	256	196-306	267	192-306
Total suspended solids	9.3	0-52	12.9	0-83	27.6	0-158
Volatile susp. solids	6.2	0-12	7.6	0-18	8.5	0-22

Note: Values in mg/l unless otherwise indicated

Table 5. Algal types and Densities, Chlorophyll-a, and Biomass in Johnson Sauk Trail Lake

(Algal densities in counts per milliliter)

Date	BG	G	D	F	O	Total	Chlorophyll-a (μg/1)	Biomass (mm^3/1)
5/12/81	150	45	75			270	20	0.735
5/26/81	280					280	30	0.400
6/09/81	900				5	905	40	3.505
6/23/81	2645	395	100			3140	70	6.406
7/07/81	4630	1200	345	325		6500	80	72.602
7/23/81	5950	735	600	460		7745	67	149.416
8/04/81	8620	870	660	315		10465	53	24.656
8/18/81	20590	495	525	345		21955	40	35.950
0/01/81	10280	360	410	640	390	12080	47	151.411
9/16/81	16000		75		40	16115	40	26.676

Note: BG = blue-greens; G = greens; D = diatoms; F = flagellates; O = others

Table 6. Benthic Macroinvertebrates Collected from Johnson Sauk Trail Lake

(Individuals per square meter)

	Shallow station			
	6/9/81	7/7/81	8/4/81	9/1/81
Ceratopogonidae (biting midge)	43		14	
Chaoborus (phantom midge fly)	158	301	7,894	2,354
Chironomidae (midge fly)	316	14	402	43
Sphaerium (fingernail clam)	14			
Tubificidae (sludge worm)	129	345	301	230
Total	660	660	8,611	2,627
	Deep station			
Chaoborus	2,196	1,091	7,320	8,913
Chironomidae	2,052	2,454	1,220	144
Total	4,248	3,545	8,540	9,057

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THE ESTABLISHMENT OF RED CLOVER ON ACID SOILS AS INFLUENCED BY LIMING, SEED COATING, AND SELECTED *RHIZOBIUM TRIFOLII* STRAINS

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ABSTRACT

A field trial was conducted to determine the influence of liming, seed coating, and strain of acid-tolerant *Rhizobium trifolii* on establishment and first-year production of red clover (*Trifolium pratense* L.) on acid soils. The experiment was conducted during 2 years, each year on a new soil site. The initial pH of the experimental sites was 5.3. Lime, added at rates of 5 or 10 metric tons/ha, produced soil pH values of 5.9 and 6.3, respectively, in soil samples collected at a depth of 0-15 cm. Six *R. trifolii* strains and three seed-coating treatments were used. Seed was uncoated or coated with an amended lime admixture using the 'Prillcote' coating process. Parameters measured included stand count, nodulation, plant height, dry matter yield, and nitrogen content of the herbage. Red clover plant population at establishment was enhanced by seed coating but was not influenced by the strain of rhizobia added to the seed. Dry matter yields were increased the second year by liming acid soils and seed coating but were not affected by rhizobia strains used. The optimum lime:seed coating ratio varied between years. Significant differences in plant height attributable to seed coating were noted during the second year of the study. Lime application and seed coating were both important factors influencing red clover production in the year of seeding.

INTRODUCTION

The establishment and production of red clover (*Trifolium pratense* L.) in the North Central United States is frequently limited as a result of soil-related problems. Among these are poor soil fertility and pH. Lime coating of seed and selec-

tion of more acid-tolerant strains of *Rhizobium* spp. may improve stands and yields of forage legumes produced on acid sites.

In an early study of alfalfa (*Medicago sativa* L.) nodulation, Karraker (1927) grew alfalfa plants in pots with soils varying in pH by depths. He reported a reduction in nodule numbers in the acidic portion of the soil. Also, in the acidic soil a total nodule count of 8 was obtained, whereas, in the limed soil a total count of 104 was determined.

Lowther and Loneragan (1968) reported that root infection on nodule initiation had a higher calcium (Ca) requirement than either nodule devlopment or host plant growth in the presence of fixed nitrogen (N). Munns (1969) found that production of pectinase precedes infection. Pectinase activity was inhibited by acidity in the pH range of 4.5 to 5.5, which coincided with the pH range that has been shown to be inhibitory to root hair infection. He indicated that the pH optimum for pectinase activity may determine the pH at which nodulation will take place.

John et al. (1972) showed in a growth chamber experiment that increased yields and a decreased growth period to reach harvest stage were the beneficial effects of lime application and could be attributed to reduction in the concentration of aluminum (Al) and manganese (Mn). Munns et al. (1977) stated that increased nodulation and plant N content agreed with the conclusion that, for most species, growth improvement associated with liming was due to improved N fixation.

Increasing the inoculation rate per seed markedly enhanced the growth of white clover (*Trifolium repens* L.) and could replace the need to use lime-coated seed on some moderately acid soils (Lowther, 1974; Lowther, 1975; Lowther and Loneragan, 1968). Baker et al. (1968) noted that, when soil moisture was adequate during establishment, maximum alfalfa yields were obtained with lime pelleting when soil acidity levels were below pH 5.9.

According to Date (1970), the inoculant rhizobial population must develop rapidly. Low rhizobial numbers can mean delays in nodule initiation with subsequent growth retardation and even stand loss. Chatel and Greenwood (1973) concluded from their studies that the ability of *R. trifolii* to colonize a host and become established in soil varied with the strain tested.

The interrelationships of liming, seed pelleting, and introducing selected *Rhizobium* spp. to field soil have not been investigated thoroughly under midwestern United States climatic and soil conditions. Previous studies have not examined the effects of lime application on the plant growth response to seed coating and the microbial response to seed coating and lime application. The objectives of this study were to determine the influence of seed coating, selected *R. trifolii* strains, and rates of lime application on establishment and seeding year production of red clover when grown on acid soils.

MATERIALS AND METHODS

This 2-year study was conducted at the Cooperative Agronomy Research Center, Southern Illinois University, Carbondale, IL, on two adjacent sites which had been in permanent sod. A new site was used each year to prevent changes in the indigenous rhizobial population from exerting an influence on the second year's treatments. The soil on both experimental sites was a Stoy, fine-silty, mixed

mesic, Aquic Hapludalf. The sites were fall plowed to incorporate lime at the rate of 0, 5, and 10 metric tons/ha. Soil samples collected after application of lime had pH values of 5.3, 5.9, and 6.3 (0 to 15 cm deep) for the 0, 5, and 10 metric ton/ha lime treatments, respectively. Levels of soluble Mn in the soil were very high (90 to 127 ppm), soluble Al levels were low (3 to 19 ppm), and Ca and molybdenum (Mo) levels were moderate to high (800 to 1500 ppm and 0.1 to 0.3 ppm, respectively) at all lime rates.

In 1978 a factorial design was used, and in 1979 a split-plot design was used. Four replications of each seed treatment were used both years. Plot size was 1 m by 5 m. A broadcast application of 112 kg/ha $P_2 0_5$ and 224 kg/ha K_2O was made prior to final seedbed preparation. Before planting, the herbicide EPTC (S-ethyl dipropylthiocarbamate) was applied to the soil at the rate of 0.7 liters/ha a.i. and incorporated.

Red clover (cv. 'Kenland') seeds from the same lot with a germination of 96% were coated with an amended lime admixture (0.56 g thiram, 1% MgO, 1% K_2SO_4, Ohio peat inoculant plus peat per 200 g seed) and inoculated with *R. trifolii*. These seeds were planted with a 'Planet Jr.' seeder on May 1, 1978, and May 23, 1979, in rows 20 cm apart. The *R. trifolii* used in this study were provided by CelPril Industries, Inc. and were selected on the basis of acid soil tolerance from a wide geographical area. For comparison, a commercial inoculant was used for one treatment. The strains, inoculation rate, and seed-coating mixture used in this study are listed in Table 1. Seeding rates were 5.4, 8.3, and 10.8 kg/ha for red clover and coating ratios of 0:1, 0.5:1, and 1:1 (kg of lime:kg of seed), respectively. Irrigation was applied as necessary.

Stand density was measured 3 and 6 weeks after planting by counting the number of plants per m^2. Plant height was used as an index of seedling vigor and was measured 6 weeks after planting. Root nodulation was rated 6 weeks after sowing and 3 weeks after the first harvest. Nodulation ratings were done visually. Ratings were based on the number of plants out of five selected at random from each plot which exhibited effective nodulation (pink nodules). Dry matter yield determinations were made at the half bloom stage by harvesting 4 m^2 from each plot. Dried plant samples were ground to pass a 2-mm screen and analyzed for nitrogen content using the Kjeldahl method. Data for each year were evaluated by analysis of variance. Significant means were separated by using orthogonal contrasts at the 5% level of significance.

RESULTS AND DISCUSSION

Seed coating improved stands at 3 and 6 weeks over the control in both 1978 and 1979, regardless of lime rate (Table 2). The differences were highly significant. In 1978, there was no difference at 3 weeks in stands where seed coat ratio of 0.5:1 and 1:1 had been used. However, by 6 weeks a small, but significant, difference was evident between the seed coatings, with plots seeded with the 1:1 coating ratio having the better stand. In 1979, the stand from the 0.5:1 seed coating was significantly higher at both 3 and 6 weeks. The plant counts generally increased with higher seeding rates.

Liming did not influence plant populations except at 6 weeks in 1978 when the 10 metric ton/ha lime rate produced denser stands than the 5 and 0 metric ton/ha lime rates (Pr F = 0.0102). A lime by seed coating interaction was not

significant. Scott (1975) stated that seed coating influences stand development in the first 3 weeks of plant development with its influence becoming less recognizable as seedling development continues and subsequent germination of non-coated seeds takes place. From our results, it appears that seed coating influenced stand development to at least 6 weeks.

The decrease in plant population between 3 and 6 weeks in 1978 was due to insufficient rainfall which caused many of the seedlings to die. Irrigation was applied after the 6-week measurements were made. In 1979, dry weather conditions prevailed again and supplemental water was applied soon after planting. Dowling et al. (1971) reported that lime-coated seed imbibed at a fast initial rate with non-limiting water, resulting in higher germination of coated seed. It is quite likely that the presence of adequate soil moisture during germination contributed to the increased number of plants observed with the coated seed than with the raw seed. There were fewer red clover plants m^2 in 1979 than 1978 at 3 weeks. This was attributable to soil crusting in 1979 which limited seedling emergence.

Seed treatment, seed coating, and *R. trifolii* strain selection failed to produce any discernible differences in the number of plants nodulated either 6 weeks after planting or 3 weeks after the first harvest. The non-inoculated seed treatments, (Table 1), showed average nodulation. This result suggests that the indigenous rhizobial population responded to the introduction of red clover to the site by multiplying, infecting, and nodulating the clover roots. Furthermore, effects of the *R. trifolii* pelleted onto the seed may have been masked by the build-up of the indigenous rhizobial population and were undetectable by our methods. When 10 metric/tons/ha were applied in 1978, liming significantly increased nodulation above the control 6 weeks after planting (Pr F = 0.0061) and 3 weeks after the first harvest (Pr F = 0.0304) (Table 3). The first harvest was made about 70 days after planting and the second harvest about 50 days later. Again, the decrease in nodulation between sampling dates in 1978 was likely due to moisture stress.

Red clover plant height was not affected by liming in either year of the study. Seed coating significantly increased plant height in 1979 (Pr F = 0.009) over all lime rates. The 0.5:1 coating produced plants that were taller than the other treatments. A lime by seed coating interaction was not significant.

Due to a weed infestation after the first harvest in 1978, only one red clover cutting was obtained, however, two harvests were made in 1979. There was no significant difference among first harvest yields in 1978 and 1979 due to lime application. The second red clover harvest showed liming increased dry matter yields (Pr F = 0.002). This suggests that the yield response of red clover to applied lime is delayed. Both the 10 and 5 metric ton/ha lime rates produced more total dry matter than the control in 1979 (Table 4).

Seed coating increased first and second harvest dry matter yields in 1979 (Table 5); however, the increase for the 1:1 coated seed was not significant in the first harvest. The increased yields due to seed coating can be attributed to greater plant numbers as well as to increased height of the plants. The effects of seed coating and lime application appear to complement one another; the seed coating influences seedling establishment and liming influences stand productivity from the first harvest onward. Again, the lime rate by seed coating interaction was not significant.

Herbage N content was not enhanced by any strain of *R. trifolii* used in this

study or by liming as Munns (1977) suggested. Likewise, no difference for other parameters measured could be attributed to strain of *R. trifolii* used. This suggests that the inoculant strains introduced were unable to compete with or were no more effective than the indigenous population of *R. trifolii* that were present in the soil. Chatel and Greenwood (1973) also concluded that the ability of *R. trifolii* to colonize a host and become established in soil varies with the strain tested.

In conclusion, seed coating was shown to increase red clover stands, regardless of lime application, in both years of the study. Increase in plant population and plant height in response to seed pelleting produced higher dry matter yields than the non-coated seed in the second year of the study. The response of red clover to added lime appeared to be delayed, becoming evident in the regrowth the first harvest. The results suggest that seed coating and lime amendments complement each other and improve the seasonal productivity of red clover stands. Liming also tended to increase the number of plants nodulated, but not consistently. No evidence was found that any of the *R. trifolii* strains used were superior to the indigenous rhizobial species in their abiltiy to produce nodulation and fix atmospheric nitrogen.

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Table 1. Red clover seed treatments for 1978 and 1979.

Treatment	Inoculant Strain	Number of Rhizobia X 10^6/seed	Seed Coat Ratio +
			kg of lime: kg of seed
1	Nitragin "AB"	‡	not coated
2	2751	50	0.5:1
3	2751	50	1:1
4	27631	50	0.5:1
5	27631	50	1:1
6	2233	50	0.5:1
7	2233	50	1:1
8	2764OP	50	0.5:1
9	2764OP	50	1:1
10	2207	50	0.5:1
11	2207	50	1:1
12	none	none	0.5:1
13	none	none	1:1
14	2751	50 +	0.5:1

+ All treatments except #1 contain the following: 0.56 G. Thiram, 1% Mg0, 1% K_2SO_4, Ohio peat inoculant plus Peat per 200 G of seed.
‡Number of rhizobia/seed were not determined for this treatment. The treatment was not included in 1979.

Table 2. The effect of lime coating red clover seed on stands at 3 and 6 weeks.

Seed Coat Ratio (kg of lime: kg of seed)	3 weeks	6 weeks
1978 (Planted May 1)	----------Plants/m^2----------	
0:1	177	96
0.5:1	236	124
1.0:1	255	144
Contrast 0 vs 0.5 and 1.0	**	**
1979 (Planted May 23)		
0:1	98	75
0.5:1	153	157
1.0:1	109	118
Contrast 0 vs 0.5 and 1.0	**	**
Contrast 0.5 vs 1.0	**	**

**Significant at the 5 and 1% level, respectively.

Table 3. Mean root nodulation of red clover 6 weeks after planting 1 May 1978 and 28 May 1979 and 3 weeks after the first harvest as influenced by lime.

Lime	Nodulation Rating‡			
	6 weeks after planting		3 weeks after first harvest	
(Metric ton/ha)	1978	1979	1978	1979
0	1.8	3.1	0.55	4.7
5	3.5	3.3	0.64	4.9
10	4.0	3.5	1.07	4.9
Contrast				
0 vs 5 and 10	**	NS	**	**
Contrast				
5 vs 10	NS	NS	**	NS

‡Ratings were based on visual evaluation of 5 plants randomly selected from each plot. The rating scale ranged from 0 (poor nodulation) to 5 (excellent nodulation).
**NS. Significant at the 1% level, and not significant respectively.

Table 4. Total seasonal dry matter yield of red clover as influenced by lime application during 1978 and 1979.

Lime Rates	Dry Matter Yields (Kg/ha)	
(Metric tons/ha)	1978 (One harvest)	1979 (Two harvests)
0	1,423	4,592
5	1,423	5,371
10	1,498	6,012
Contrast		
0 vs 5 and 10	NS	**
Contrast		
5 vs 10	NS	**

**NS. Significant at the 1% level, and not significant respectively.

Table 5. Effect of seed coating on dry matter yields of red clover, 1979.

Seed Coating Ratio (kg of lime: kg of seed)	First harvest (Aug. 1)	Second harvest (Sept. 20)
	kg/ha	
0:1	1,114	3,059
0.5:1	1,693	3,971
1.0:1	1,355	3,824
Contrast 0 vs 0.5 and 1.0	*	**
Contrast 0.5 vs 1.0	**	NS

*, **, NS. Significant at the 5 and 1% level, and not significant, respectively.

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RELATIONSHIP BETWEEN POPULATION DENSITY OF ADULT NORTHERN LARGEMOUTH BASS, *MICROPTERUS SALMOIDES SALMOIDES*, AND POND PRODUCTION OF YOUNG-OF-THE-YEAR

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ABSTRACT

Adult largemouth bass were stocked into three 0.08-hectare experimental ponds at three different densities (50, 150 or 300 individuals per hectare). The number of offspring censused in the low, moderate and high density ponds were 79,288, 58,863 and 17,413 per hectare, respectively. The data indicate a negative relationship between the density of adults stocked and the number of juvenile largemouth bass produced.

INTRODUCTION

Many factors are involved in determining the success of largemouth bass, *Micropterus salmoides*, reproduction and recruitment. It has been postulated that under certain types and degrees of competition, the disappearance of some populations of game fishes may be associated with the inability to successfully spawn (Bennett, 1954). Variations in chemical and physical characterisitics of a pond have been shown to affect the success of largemouth bass spawning. High pH, fluctuating water levels, temperature changes, and composition and abundance of other fish species may be important in limiting reproduction (Bennett, 1954; Buck and Thoits, 1970; Barwick and Holcomb, 1976; Smith, 1976).

A negative relationship was found between the number of largemouth bass spawners and the number of fry produced in Ridge Lake, Illinois during 1941-51 (Bennett, 1954; Bennett et al., 1969). Buck and Thoits (1970) studied one-species populations of smallmouth, *Micropterus dolomieui*, and largemouth bass in 0.4-hectare ponds in Illinois. They found that the number of young-of-the-year largemouth bass produced was inversely correlated with the number of adult largemouth bass stocked. However, this was not found to be true for smallmouth bass populations. It should be noted that fingerlings and subadults were also present in these ponds. Rickett (1976) found that when adult largemouth bass and black bullheads, *Ictalurus melas*, were cultured together, ponds with larger number of largemouth bass resulted in a depletion of the young of both species. Other studies of largemouth bass, however, indicated that the degree of reproductive success is not affected by the density of brood stock (Stroud and Jenkins, 1962; Johnson and McCrimmon, 1967).

This study investigates the relationship between the number of largemouth bass spawners and the resulting abundance of young-of-the-year in small ponds in central Illinois which contained fathead minnows, *Pimephales promelas*, as forage.

METHODS

This study was conducted at the Aquatic Research Field Laboratory of the Illinois Natural History Survey, located on the Urbana-Champaign campus of the University of Illinois. Northern largemouth bass, *M. s. salmoides*, collected from a 5.7-hectare central Illinois lake, were stocked into three adjacent 0.08-hectare experimental ponds in October 1978. Pond A (low density) was stocked with two male and two female largemouth bass (50 bass per hectare); Pond B (moderate density) was stocked with six male and six female (150 bass per hectare); and Pond C (high density) was stocked with 14 male and 10 female (300 bass per hectare). All largemouth bass were weighed, measured, and tagged prior to introduction,

and the mean total lengths and weights were similar among ponds (Table 1). Each of the three ponds was stocked with approximately 1.70 kg of fathead minnows, *Pimephales promelas*, as forage. No other fish were present in the experimental ponds.

Fishing was conducted for one week in the fall of 1978 and seven weeks in the spring of 1979 as a component of a study not reported here. All largemouth bass caught were returned to the ponds. Substantial spawning had occurred in all ponds prior to initiation of fishing on 22 May, and later, large schools of largemouth bass fry were observed in all three ponds. The ponds were drained between 26 July and 6 August 1979, at which time the adult largemouth bass originally stocked were recovered. A complete population census of the juveniles was conducted for each pond. Samples of 100 offspring from each pond were individually measured for total length to obtain length-frequency distributions and then group weighed to calculate mean weights. Abnormally large fingerlings (over 50 mm) were present in Pond A (low density) only; mean total length and weight were calculated separately for these larger fingerlings.

RESULTS AND DISCUSSION

Considerable differences occurred in the number, mean lengths and mean weights of offspring between the three ponds (Table 2). At the time of draining, Pond A (low density broodstock) contained 6,263 young-of-the-year largemouth bass averaging 34 mm and 0.6 g. Offspring from Pond B (moderate density broodstock) total 4,549; mean length was 47 mm and mean weight was 1.4 g. The fewest offspring(1,393) were recovered from Pond C (high density broodstock), although these were larger in mean length (51 mm) and mean weight (1.9 g).

When the three ponds were drained, fathead minnows remained only in Pond A (approximatly 3.50 kg) (43.75 kg/ha). There was little correlation ($r = 0.406$) between the number of spawners and the total weight of juveniles produced, but a highly negative correlation ($r = -0.999$) existed between the number of spawners and the number of juveniles produced (Fig. 1).

Although the larger number of females present in the moderate and high density ponds had the cumulative potential to produce more offspring than the females in the low density pond, total offspring survival after three months was highest in the low density pond. During this period, only the adult largemouth bass in the low density pond gained considerable weight (25.2%, Table 1). This weight gain apparently resulted from the relatively large amount of forage available. In addition, this abundance of forage also lowered the predation rate on the young-of-the-year largemouth bass. This high survivability resulted in the production of more juvenile bass per hectare, but smaller mean size (Table 2).

It has been reported that young-of-the-year largemouth bass feed mostly on invertebrates until they are 120-149 mm long (Applegate and Kruckenberg 1978). The offspring in our experiment did not have a large predatory impact on the forage fish because few grew large enough to consume the minnows. In addition, Johnson and McCrimmon (1967) reported that in a series of brood ponds with various combinations of largemouth bass and forage fish, the mean weight of fingerlings was not affected by the density of fingerlings produced in these ponds. This was not the case in the present study; both mean total lengths and weights of

the offspring were negatively correlated to their density ($r = -0.898$ and -0.955, respectively).

The length-frequency distribution of the juvenile bass for all three experimental ponds is shown in Figure 2. Only Pond A contained some juvenile largemouth bass believed to be cannibals (not shown in Figure 2), which were much larger than the other fingerlings. Following the final census, several of these larger fish regurgitated small conspecifics. The presumed cannibals ($N = 81$) had a mean weight of 5.1 g and a mean total length of 72 mm. The cannibals recovered from the pond made up 1.3 percent of the number and 9.2 percent of the total weight of offspring. The length-frequency distribution in Pond B was closer to a normal distribution. Analysis of the length-frequency distribution of Pond C revealed a bimodal distribution. This bimodal distribution in Pond C might be due to cannibalism, however, the fairly small difference in size between the two classes does not strongly support this. In fact, temporal differences in spawning may be a more plausible explanation.

The lack of an adequate initial forage base in the moderate (Pond B) and high (Pond C) density brood ponds, confirmed by the loss of weight in the adults, could have resulted in increased predation on the young-of-the-year largemouth bass. The negative correlation between adult density and the density of fingerlings produced appears to result directly from the food resources available to the adults.

However, it is possible that factors other than food availability to adult broodstock have contributed to the resulting population densities of the young-of-the-year largemouth bass. Aggressive interactions due to territorially and competition between individual males for females may have prevented the successful spawning of some fish in the higher density ponds. Davis (1966) stated that behavioral competition with other members of the same species may disrupt complex courtship behavior patterns. Such competition would be more pronounced in denser populations. However, apparently there was adequate nesting space in each of the three ponds (Beaty and Childers, 1980), for all of the potentially nesting males present, although the actual number of successful nests in each pond is not known. Therefore, suppression of spawning through competition for nesting sites is not considered an important factor in this study. Differential physicochemical and biotic parameters among ponds may also have been responsible for fry/fingerling survival and food production (Buck et al., 1970). However, because the three experimental ponds were very similar in morphology and morphometry, as well as macrophyte cover, we believe that these parameters did not contribute extensively to the variation observed among ponds in the juvenile largemouth bass densities. In our experiment, the density of the broodstock appeared to have the greatest influence on the abundance of surviving young-of-the-year largemouth bass.

Current hatchery procedures are raising large numbers of largemouth bass fingerlings for stocking purposes using a substantial number of adult fish to serve as broodstock. If broodstock is to be selected continually from wild stocks (Smith and Chesser, 1981; Ryman, 1981; Philipp et., 1981, 1983), these collections may represent a substantial effort by production personnel. The procedures that maximize production efficiency should be sought and implemented. In this experiment, the lowest density of adults tested produced the highest number of surviving offspring. However, these fingerlings also had the smallest mean size. The moderate density pond (Pond B) produced a good compromise between number

and size of young-of-the-year in this experiment (Fig. 1). An optimal production procedure may be obtained by locating the point at which the graphical lines of numbers and weights of fingerlings in Figure 1 intersect. This is approximately halfway between our low and moderate density ponds. It should be noted that these estimated predictions are based on results using a single size class of adult largemouth bass as spawners in small (0.08 hectare) ponds with a single concentration of fathead minnows as forage. Changes in the forage fish stocking rates would presumably alter the resulting density and size of largemouth bass fingerlings produced.

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Table 1. Lengths and weights of largemouth bass at the time of stocking and draining. The percent of change in length and weight between stocking and draining are shown. Standard deviations are indicated in parentheses.

	Stocking	N	Draining	N	Percent of Change
Pond A (low density)		4		4	
Mean Total Length (mm)	272(9)		307(13)		+ 12.9
Mean Total Weight (g)	329(57)		412(41)		+ 25.2
Pond B (moderate density)		12		12	
Mean Total Length (mm)	271(24)		285(15)		+ 5.2
Mean Total Weight (g)	316(88)		301(41)		− 4.8
Pond C (high density)		24		24	
Mean Total Length (mm)	271(14)		278(12)		+ 2.6
Mean Total Weight (g)	314(55)		275(37)		− 12.4

Table 2. Numbers, weights, mean lengths, and mean weights of young-of-the-year largemouth bass recovered.

	Number (per hectare)	Kilograms (per hectare)	Mean Length (mm)	Mean Weight (g)
Pond A (low density)	6,263 (78,288)	3.75 (46.88)	34	0.6
Pond B (moderate density)	4,549 (56,863)	6.23 (77.88)	47	1.3
Pond C (high density)	1,393 (17,413)	2.65 (33.13)	51	1.9

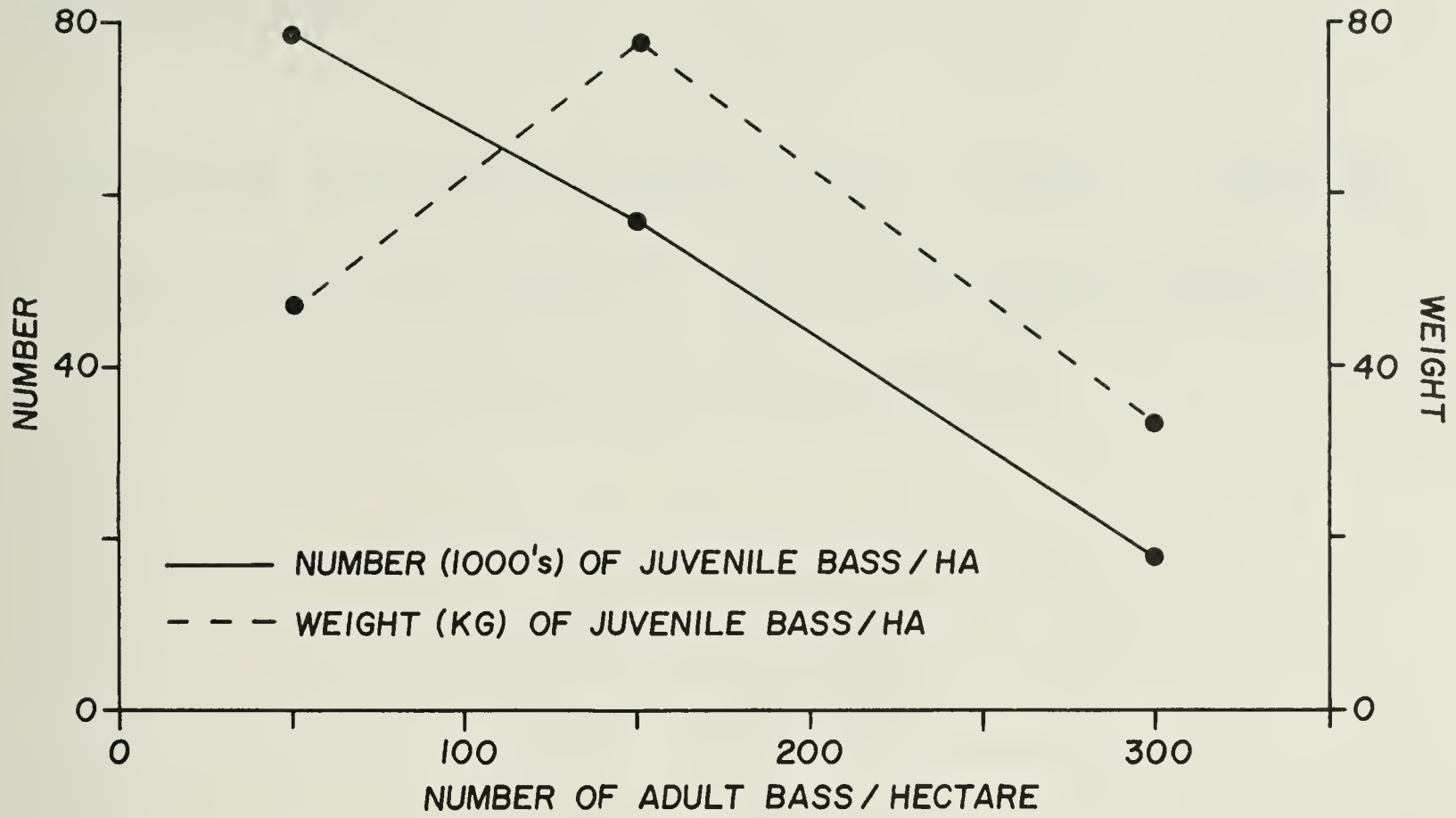

Figure 1. Number and weight per hectare of young-of-the-year largemouth bass relative to the number of adult bass stocked.

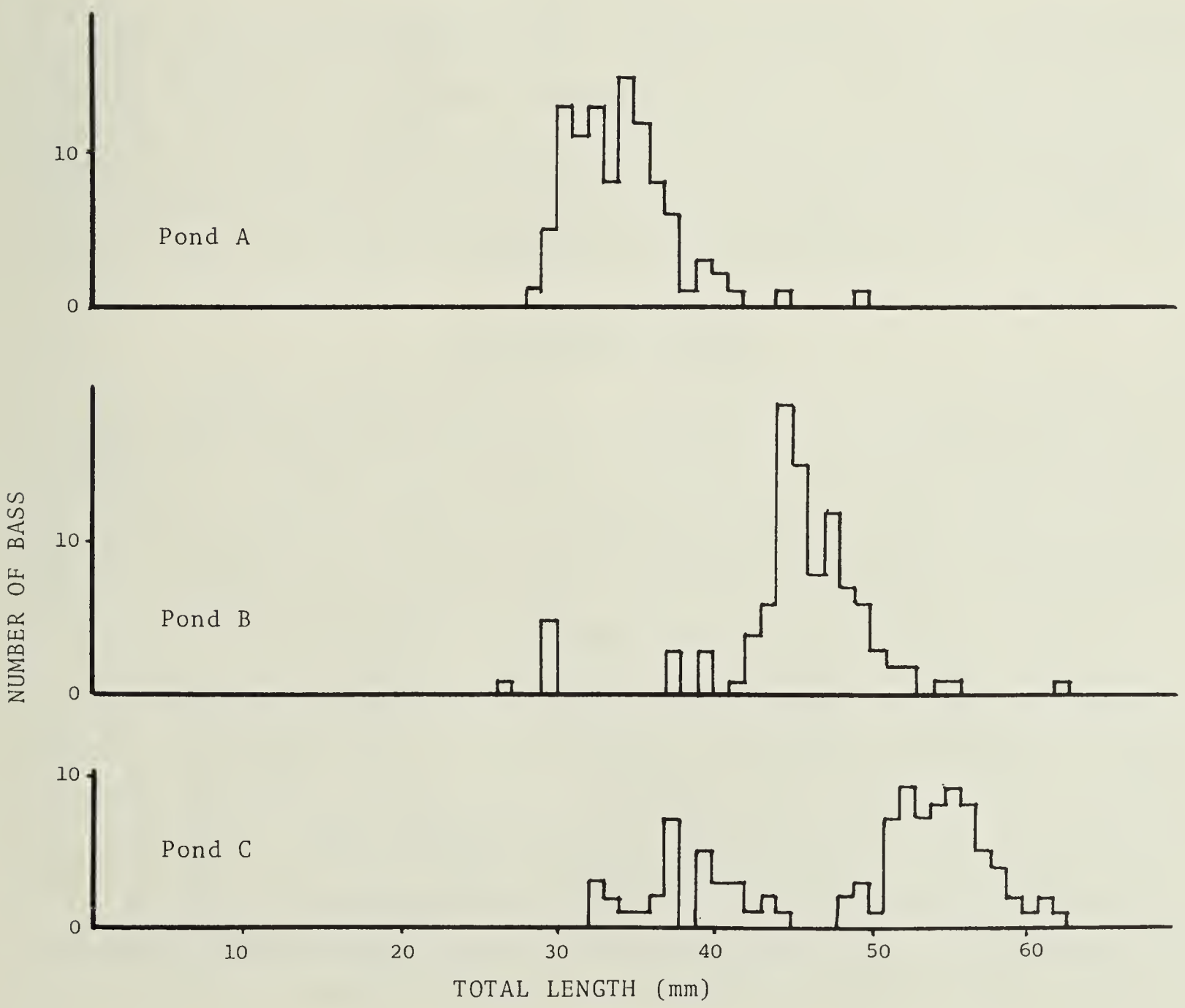

Figure 2. Length-frequency distribution of juvenile largemouth bass in low density, moderate density and high density ponds.

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WOODY VEGETATION OF A DRY—MESIC UPLAND FOREST IN CUMBERLAND COUNTY, ILLINOIS

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ABSTRACT

An inventory was completed of the woody vegetation of a dry-mesic upland forest in Cumberland County, Illinois. This woods, which is located in the Southern Till Plain Division, has a stand composition of 243 stems per hectare (above 10 cm dbh.) and 23.4 sq m of basal area per hectare. Of the 23 woody species present, white oak is the leading dominant, accounting for more than 50% of the Importance Value in the woods. Black oak, shagbark hickory, mockernut hickory, sugar maple, and red oak follow in order of importance.

INTRODUCTION

The woodlot surveyed represents a remnant of a much larger forest that once occupied upland and sloping sites associated with the Embarass River drainage in Cumberland County, Illinois. This dry-mesic upland forest is dominated by mature second growth white oak, with some hickories, other oaks, and sugar maple. It is located in the northern part of Effingham Plain Section of the Southern Till Plain Division. (Schwegman, 1973). The present study was undertaken since there are few detailed studies of the forest types of this division.

This 20 acre (8.1 hectare) woodlot is located about 13 miles south of the southern edge of the Shelbyville moraine, the terminal moraine of Wisconsin glaciation (S1/2 NE1/4 SE 1/4 Sec 35 T9N R7E), and about 8 miles SW of Toledo, Cumberland County, Illinois. It is on Illinoian till, and the soils are mostly Bluford silt loam which developed under mixed hardwood forest on undulating ground (Smith and Smith, 1940). The topography is gently rolling with a maximum difference in elevation of about 40 feet. The woodlot is well drained by two small intermittent streams, one across the western part of the tract, and the other near the southern boundary in the eastern part. Between the streams is a relatively

flat to gently rolling upland. The woods is bordered on the east by a county road, on the north and west by pasture, and on the south by a small, heavily disturbed woodlot.

MATERIALS AND METHODS

During the summer of 1983 the woodlot was divided into 126 quadrats 25 m on a side (0.1544 acres). The number, size, and species of all woody plants were recorded in each. Dead-standing trees were also measured and identified when possible. The Importance Value (IV) was then calculated from the data to provide a better basis of comparison of the various species. The determination of the IV follows the procedure outlined by McIntosh (1957), and later Boggess (1964), in which the IV is the sum of the relative frequency, relative density, and relative dominance.

An estimation of the number of seedlings and saplings of the various species was determined by using randomly located 1/10,000 and 1/1,000 hectare, nested circular plots located in each of the 25 m quadrats. The saplings (2.5-10.0 cm dbh.) were recorded on the larger plots, and the seedlings on the smaller. The seedlings were divided into those under 30 cm tall, and those over 30 cm tall but less that 2.5 cm dbh. The nomenclature follows that of Mohlenbrock (1975).

RESULTS AND DISCUSSION

A total of 23 tree species are found in the woodlot. These species along with their density and frequency by height or diameter class appear in Table 1. An additional listing of the 11 leading species encountered, with their relative values, importance values, averge diameters, and the number of individuals per hectare broken down into broad diameter classes, is included in Table 2.

Except for along the intermittent stream, in a small swampy area, and in a heavily disturbed lowland area, the overstory of the woods is relatively uniform. Along the two intermittent streams and their slopes sugar maple is extremely common. Associated species include hop hornbeam, red oak, red bud, bitternut hickory, and American elm. In the small swamp, which is less than 1/10 hectare in size and located in the northwest corner of the woods, red maple, black willow, and honey locust are found; while the heavily disturbed lowland located along the east edge of the woods and about 1/2 hectare in size, is dominated by sugar maple, hackberry, chestnut oak, and sycamore.

The remainder of the woodlot is dominated by dry-mesic upland species with white oak being, by far, the leading dominant. This species has an IV of 151 and accounts for more than half of the individuals and two thirds of the basal area in the woods (Table 2). It is not well represented in the seedling and sapling categories (Table 1), but in the other diameter classes exceeds all other species in the woods. Its importance is mainly due to the large size of individual trees, accounting for more than half of all individuals in nearly all of the higher diameter classes.

The importance of black and red oak, second and sixth in IV respectively, is due mostly to the large size of individual trees as indicated by their average diameters of 40 cm. Black oak, which is commonly associated with white oak in the uplands, is fairly well represented in the seedling (fifth) and sapling (third)

categories, but has fairly poor size class distribution with most individuals in the 1-2, 4-5, and 5-6 dm diameter classes. In contrast, red oak is poorly represented in the sapling and seedling categories. This species is commonly found in the narrow valleys associated with the intermittent stream, and also has poor size class distribution (Table 2).

Four species of hickory are found in the woods. Of these, shagbark hickory and mockernut hickory, rank third and fourth in IV respectively, mainly due to the numerous small diameter trees of these species scattered throughout the uplands. Both are fairly well represented in the seedling and sapling catagories, and rank very high in the 1 through 4 dm diameter classes. Pignut hickory (ninth in IV) is also an upland species, but is poorly represented in the lower diameter classes. Bitternut hickory (eighth in IV), in contrast, is commonly associated with the intermittent streams. This species has better size class distribution than pignut hickory, and is also better represented in the seedling and sapling categories. The fact that seedlings, saplings, and small diameter trees of most hickory species are fairly common indicates that most of these species will increase in importance in the woods. Similar results were obtained by McClain and Ebinger (1968) and Ebinger (1968) for woodlots located on the Shelbyville moraine.

The importance of sugar maple (fifth in IV) is mainly due to the large number of individuals in the 1-2 dm diameter class (Table 2). It also ranks fourth in seedlings and first in saplings in the woods (Table 1). Though scattered throughout the woodlot, it is particularly abundant along the intermittent stream, and from these areas its size and number of individuals rapidly decreases through the remainder of the woods. The large number of seedlings and saplings of this taxon, as well as its numbers in the lower diameter classes indicates that it will probably increase in importance. Also, sugar maple has a high gap phase replacement potential, and will be able to take advantage of canopy openings as some of the larger oaks die. Commonly associated with sugar maple on the mesic sites is the understory tree hop hornbeam (tenth in IV). A similar association was observed by Ebinger (1968, 1973) for two forests located on the Shelbyville moraine, and by Ebinger and Parker (1969) in the Rocky Branch Nature Preserve located just south of the moraine in Clark County, Illinois.

The other taxa included in the 11 most important species are green ash (seventh in IV) and black walnut (eleventh in IV). Both are poorly distributed in the woods, usually being associated with more mesic sites. Green ash is first in the number of seedlings per hectare (Table 1), but these seedlings appear to have poor survival value as indicated by the small number of saplings and trees per hectare for this species. In contrast, no seedlings or saplings of black walnut were observed (Table 1). Undoubtedly most of the larger walnuts have been cut, and there is no seed source present.

Most of the remaining woody species have extremely low IV's, and are mostly restricted to the more disturbed parts of the woods. A few, however, which are not important components of the overstory, are commonly found in the sapling and seedling layer. Among this group are sassafras and slippery elm which rank second and third in seedlings per hectare. Also, both are well represented in the sapling category (Table 1).

Tree mortality is not an important feature of the woodlot. The total mortality of all species combined is only 10.1 individuals per hectare with nearly 3/4 of these being relatively large white and black oaks. Also, a total of 15 cut stumps were

found, indicating relatively recent cutting. Most of these were white oaks, but a few were black walnut.

The woody composition of this woodlot is similar to many of the forests associated with the Shelbyville moraine, and the northern part of the Southern Till Plain Division in this part of Illinois. The only other woods recently surveyed in this division is located at Rock Cave Natural Area in Effingham County, Illinois (Ebinger, 1982). The composition of the two woodlots is strikingly similar. At Rock Cave, however, the woods is very immature with nearly three times as many individuals per hectare, and with very few trees in the larger diameter classes.

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Table 1. Individuals per hectare and frequency of woody species by height or diameter class in an oak-hickory forest in Cumberland County, Illinois.

Scientific Name	Common Name	Symbol	Height Class					Diameter Class			
			Density			Frequency		2.5–10.0 cm		10.0+ cm	
			<30 cm tall	>30 cm tall <2.5 cm dbh	Total	<30 cm tall	>30 cm tall <2.5 cm dbh	Density	Frequency	Density	Frequency
Quercus alba L.	White Oak	WO	237	477	714	2.3	3.2	25	2.3	140.4	98.4
Quercus velutina Lam.	Black Oak	BO	1189	872	2061	11.9	8.7	294	23.8	13.1	46.0
Carya ovata (Mill.) K.Koch.	Shagbark	Sh	872	635	1507	7.9	4.8	230	19.8	19.3	54.8
Carya tomentosa (Poir.) Nutt.	Mockernut	Mo	398	477	875	3.2	4.8	430	32.5	14.3	42.9
Acer saccharum Marsh.	Sugar Maple	SM	1033	2540	3573	9.5	21.4	452	16.7	16.3	40.5
Quercus rubra L.	Red Oak	RO	79	316	395	.8	2.4	57	5.6	7.2	28.6
Fraxinus pennsylvanica Marsh.	Green Ash	GA	6032	3731	9763	34.9	27.0	175	15.9	8.9	31.7
Carya cordiformis (Wang.) K.Koch.	Bitternut	Bi	79	237	316	.8	2.4	25	2.4	3.0	15.1
Carya glabra (Mill.) Sweet.	Pignut	Pi	--	79	79	--	.8	7	.8	2.7	12.7
Ostrya virginiana (Mill.) K.Koch.	Hornbeam	Ho	79	237	316	.8	1.6	94	4.8	4.0	11.1
Juglans nigra L.	Black Walnut	BW	--	--	--	--	--	--	--	2.0	10.3
Prunus serotina Ehrh.	Black Cherry	BC	477	793	1270	4.8	7.1	94	7.9	2.7	10.3
Ulmus rubra Muhl.	Slippery Elm	SE	566	4287	4843	5.6	15.1	136	11.1	2.2	7.9
Cercis canadensis L.	Redbud	Rb	316	79	395	3.2	.8	57	4.0	1.2	7.9
Ulmus americana L.	American Elm	AE	--	--	--	--	--	7	.8	1.5	7.1
Sassafras albidum (Nutt.) Ness.	Sassafrass	Sa	3254	3731	6985	18.3	23.0	190	11.1	1.5	5.6
Celtis occidentalis L.	Hackberry	Ha	--	--	--	--	--	7	.8	.7	3.2
Quercus muhlenbergii Englem.	Chestnut Oak	CO	--	--	--	--	--	--	--	.7	2.4
Gleditisia triacanthos L.	Honey Locust	HL	--	--	--	--	--	--	--	.7	1.6
Morus rubra L.	Red Mulberry	RM	--	158	158	--	1.6	25	2.4	.2	1.6
Plantanus occidentalis L.	Sycamore	Sy	--	--	--	--	--	--	--	.2	.8
Acer rubrum L.	Red Maple	Re	--	--	--	--	--	--	--	.2	.8
Salix nigra Marsh.	Black Willow	Bl	--	--	--	--	--	--	--	.2	.8
Totals			14601	18649	33250			2305		243.2	

Table 2. Number of trees and basal areas per hectare, relative values, diameter classes, and average diameters for the leading dominants in an oak-hickory forest in Cumberland County, Illinois.

Species	Basal Area (m^2/ha)	Density (stems/ha)	RELATIVE VALUES				NUMBER OF TREES PER HECTARE BY DIAMETER CLASS (dm)						Av. Diam. (cm)
			Relative Frequency	Relative Density	Relative Dominance	Importance Value	1-2	2-3	3-4	4-5	5-6	6+	
WO	16.7	140.4	22.3	58.0	71.1	151.4	11.0	27.3	47.1	38.1	15.0	1.9	37
BO	1.9	13.1	10.4	5.3	8.1	23.8	2.9	.6	1.5	4.5	3.0	.6	40
Sh	.8	19.3	12.4	7.9	3.3	23.6	9.3	6.9	2.7	.4	--	--	21
Mo	.8	14.3	9.7	5.9	3.6	19.2	5.3	4.1	4.3	.5	.1	--	26
SM	.7	16.3	9.2	6.8	3.0	19.0	10.8	2.0	1.5	1.8	.2	--	20
RO	1.1	7.2	6.4	2.9	4.7	14.0	1.7	1.0	.3	1.3	2.0	.9	40
GA	.6	8.9	7.2	3.7	2.4	13.3	5.2	1.2	.6	1.2	.6	.1	24
Bi	.1	3.0	3.4	1.2	.5	5.1	1.8	.6	.6	--	--	--	21
Pi	.2	2.7	2.9	1.1	.7	4.7	.5	1.3	.8	.1	--	--	28
Ho	.1	4.0	2.5	1.6	.3	4.4	4.0	--	--	--	--	--	14
BW	.1	2.0	2.3	.8	.6	3.7	.2	.9	.9	--	--	--	15
Others	.3	12.0	11.3	4.8	1.7	17.8	9.7	1.6	.4	--	--	.3	--
Totals	23.4	243.2	100.0	100.0	100.0	300.0	62.4	47.5	60.7	47.9	20.9	3.8	

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TYPE SECTION OF THE YANKEETOWN FORMATION

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ABSTRACT

A type section is designated for the Yankeetown, Fm. (Upper Mississippian), a predominantly clastic unit exposed in southwestern Illinois and southeastern Missouri. The type section consists of exposures in the SE 1/4 NE 1/4 NE 1/4 NE 1/4 Sec. 26, N 1/2 NW 1/4 NW 1/4 Sec. 25, and S 1/2 SW 1/4 SW 1/4 Sec. 24, T.4S., R. 9W., Monroe County, Illinois.

TEXT

The Yankeetown Formation was named by Stuart Weller (1913) from exposures near Yankeetown School in the southeast corner of Monroe County, Illinois. The Yankeetown Formation conformably overlies the Renault Formation, with which it interfingers in places, and is conformably overlain by the Paint Creek Formation. Weller (1913) described the Yankeetown Formation as a light buff to white, dominantly siliceous unit with lesser amounts of siliceous to sandy limestones and quartzitic rock. The Yankeetown Formation according to Weller and Weller (1939) consists largely of fine-grained sandstone that has been altered by long term weathering to a sandy chert or "quartzite". In addition, layers of shale are described and in places thin limestones are said to be present. The limestone is decribed by Weller and Weller (1939) as "varying from dense and siliceous to coarsely crystalline and arenaceous". The bedding of the Yankeetown Formation has been described as even to very irregular (Weller, 1913 and Weller and Weller, 1939). Willman, et al. (1975) describe the Yankeetown Formation as a sandstone-shale unit in southwestern Illinois.

Stuart Weller (1913) did not designate a type section for the Yankeetown but stated that "some excellent and typical exposures of the formation may be seen in the region about Yankeetown School". Yankeetown School was located in the NE 1/4 SE 1/4 SE 1/4 Sec. 26, T. 4 S., R. 9 W., Monroe County, Illinois (see Renault 15' Quadrangle map), although it is no longer present at that site. Weller and Weller (1939) stated that "the Yankeetown Chert is well-exposed along the road

northeast of Yankeetown School and also a half mile farther north in the northwest corner Sec. 25, T. 4 S., R. 9 W.". Willman, et al., (1975) give the type section as northeast corner SE 1/4 Sec. 26, T. 4 S., R. 9 W. However, there are no exposures of the Yankeetown at that location, which is, therefore, an inappropriate designation for a type section. The best exposures of the Yankeetown that we have been able to locate in the vicinity of the original site of Yankeetown School are in the northwest corner of Sec. 25, T. 4 S., R. 9 W., an outcrop mentioned by Weller and Weller (1939). The other outcrop of the Yankeetown Formation mentioned by Weller and Weller (1939) near the original site of Yankeetown School consists of only about three feet (one meter) of strata with neither the top nor the base of the formation exposed.

Since no adequate type section for the Yankeetown Formation has been described previously, it is appropriate to designate exposures in and along the northeast-flowing tributary to Horse Creek in the SE 1/4 NE 1/4 NE 1/4 NE 1/4 Sec. 26, N 1/2 NW 1/4 NW 1/4 Sec 25, and S 1/2 SW 1/4 SW 1/4 Sec. 24, T. 4 S., R. 9 W., Monroe County, Illinois (Ames Quadrangle) as the type section of the Yankeetown Formation (Fig. 1, 2). The exposures of the type Yankeetown include the basal contact with shales currently referred to the Renault Formation. Although the top is not exposed in these outcrops, it is exposed to the south at the type section of the Paint Creek Formation in the NE 1/4 SW 1/4 NE 1/4 Sec. 2, T. 5 S., R. 9 W., Monroe County, Illinois (see Fig. 1). At its type section the Yankeetown Formation included quartz-cemented sandstone, quartz-cemented siltstone, and sandy limestone, which are the most abundant rock types in it throughout the outcrop area. Small amounts of shale are present in the Yankeetown at other sites, however. The extent of quartz cementation is much greater than the amount found in any other clastic unit in the Illinois Basin, and is thus diagnostic for the Yankeetown. In spite of the lithologic variability of the Yankeetown, the diagnostic quartz-cemented, chert-like, clastic rock is consistently present in the southwestern Illinois outcrop belt.

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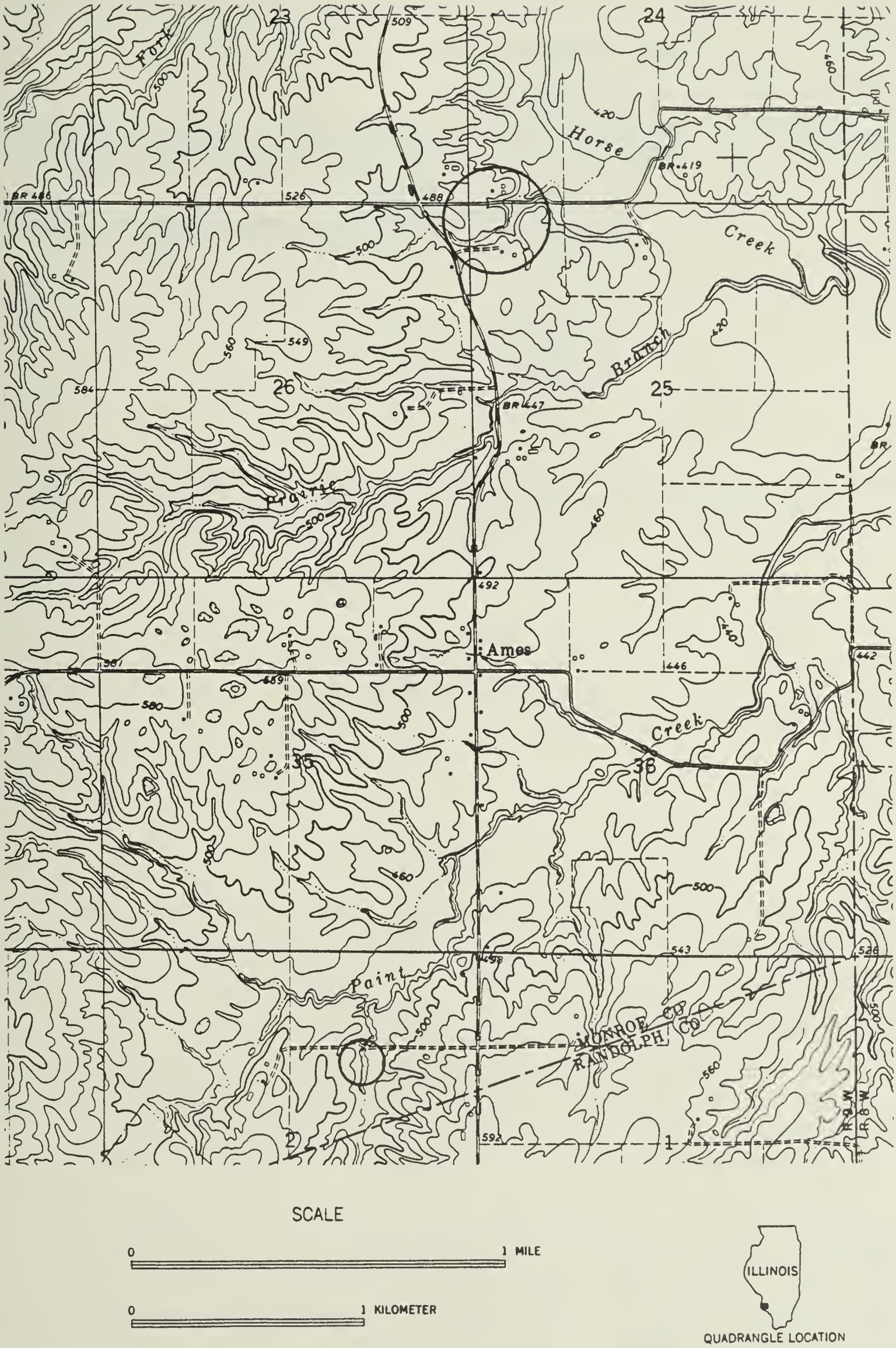

Figure 1. Part of the Ames Quadrangle. Large circle shows location of the type section of the Yankeetown Fm. Small circle shows location of exposures of the upper contact of the Yankeetown Fm. at the base of the type section of the Paint Creek Fm.

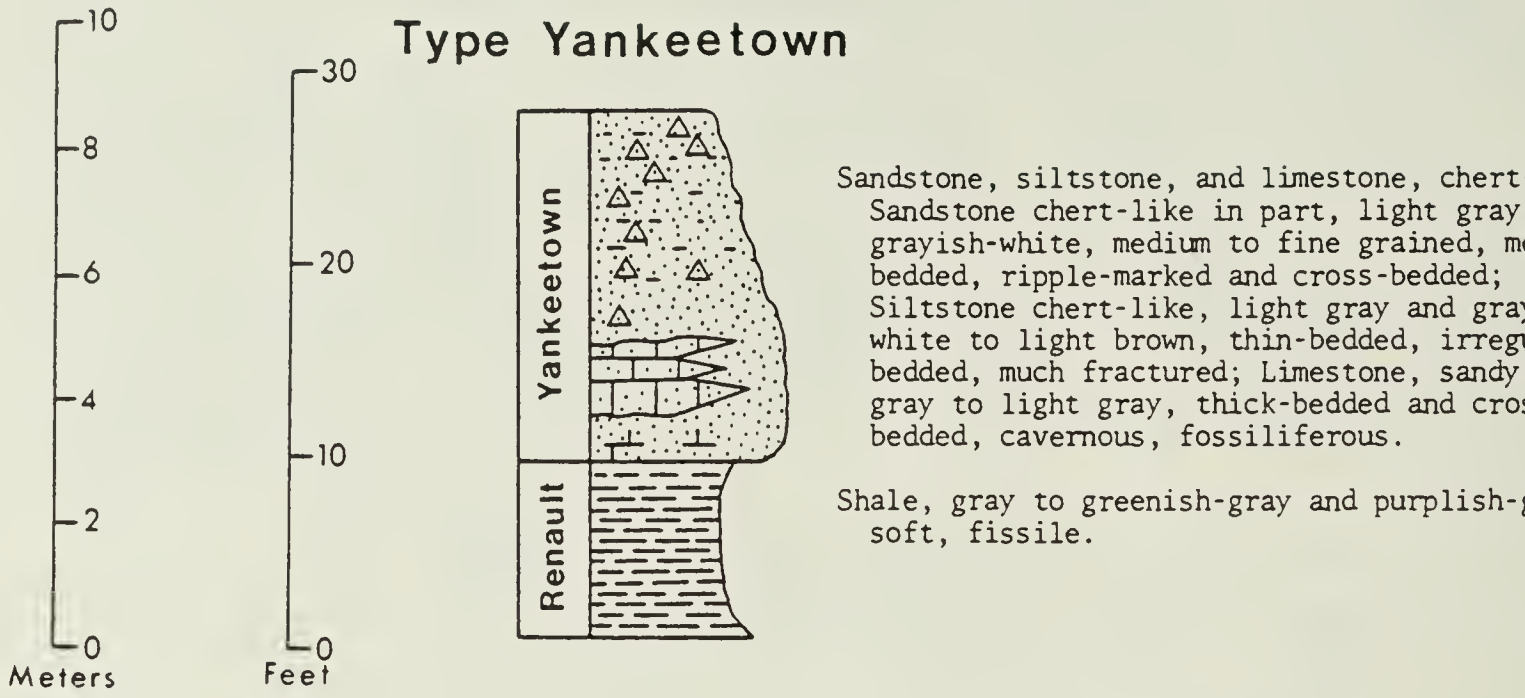
Type Yankeetown
10
8
6
4
2
0
Meters
30
20
10
0
Feet
Yankeetown
Renault
Sandstone, siltstone, and limestone, chert-like; Sandstone chert-like in part, light gray to grayish-white, medium to fine grained, medium bedded, ripple-marked and cross-bedded; Siltstone chert-like, light gray and grayish white to light brown, thin-bedded, irregularly bedded, much fractured; Limestone, sandy, gray to light gray, thick-bedded and cross-bedded, cavernous, fossiliferous.
Shale, gray to greenish-gray and purplish-gray, soft, fissile.

Figure 2. Geologic column of exposures at the type locality of the Yankeetown Formation in the SE 1/4 NE 1/4 NE 1/4 NE 1/4 Sec. 26, N 1/2 NW 1/4 NW 1/4 NW 1/4 Sec. 25, and S 1/2 SW 1/4 SW 1/4 Sec. 24, T. 4 S., R. 9 W., Monroe County, Illinois.

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ANALYSIS OF ILLINOIS WILD TURKEY HABITAT[1]

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ABSTRACT

A vegetation analysis of wild turkey habitat was conducted in the Illinois' counties of Alexander, Calhoun, Jackson, and Union. From these studies it was determined that wild turkey inhabit relatively open stands of timber with agricultural fields and forest openings in proximity. Species of *Quercus* comprise approximately 40% of more of the trees samples, with *Q. alba*, *Q. rubra*, and *Q. velutina* being the most important. Common associates include *Carya* spp., *Cornus florida*, *Acer saccharum*, *Sassafras albidum*, *Fraxinus americana*, and *Ulmus rubra*. Though generally associated with dense forest, the present study revealed that wild turkeys readily adapt to more open agricultural areas with the increased edge effect.

In 1959, with the release of wild trapped stock obtained from Mississippi, West Virginia, and Arkansas, the Illinois Department of Conservation initiated a restocking program that would successfully restore the Eastern Wild Turkey (*Meleagris gallopavo silvestris*) to its original range in Illinois (Calhoun, 1966). The success of this program is best evidenced by the fact that the turkey population was high enough in 1970 in Alexander, Jackson, and Union counties to warrant the first legal season since their disapparance from the state (Cottingham,

[1]Supported in part by the Illinois Chapter of the National Wild Turkey Federation.

1974). Pope and Calhoun Counties were opened to hunting in 1972 and 1978 repectively.

Lindzey (1967) noted that the turkey habitat criterion which presumes that large tracts of timber with little or no human interference were required, has been modified as the wild turkey is returned to its original range. Birds in Iowa, Pennsylvania, New York, Texas, and Illinois, have been reported in relatively close association with humans. Truly wild turkeys, however, seem to thrive best in areas with minimal human contact. The purpose of the present study is to determine the type of habitat in which high concentration of wild turkey occur in Illinois.

MATERIALS AND METHODS

The field study areas were determined by utilizing data collected at hunter check stations during the spring turkey seasons. Data were available for Alexander, Jackson, and Union Counties from 1970-1979, Pope County for 1972-1979, and Calhoun County for 1978-1979. Kill locations were recorded by township, range, and section numbers. Sections with high kill concentrations were selected for subsequent field studies. Three sections in Alexander, Calhoun, and Union Counties, and two sections from Jackson County were selected. Pope County was eliminated from the study due to the absence of kill concentrations.

The general habitat of each section was determined from 1974 black and white aerial photographs obtained from the USDA Agricultural Stabilization and Conservation Service. From these photographs the km of roads, the km of edge, and the percent of forests, fields, and orchards for each section was obtained with the use of a Lasico compensating polar planimeter. The number of occupied dwellings was determined by driving all roads in each section.

Within each section a randomly located forest, at least 20 ha in size, was sampled using a 3 BAF metric wedge prism. Within this forest 20 study plots were randomly located about 40 m apart along a compass line through the area. The total number of individuals of each species in each plot was recorded (Dilworth and Bell, 1976). From these data the basal area (m^2/ha), relative dominance, and relative frequency for each tree species was determined using the procedure outlined by Ebinger (1982). At every other sample point for the metric wedge prism a 0.025 ha circular plot was located. In these plots the trees were tallied by species into 10 cm dbh. diameter classes. From these data the density, relative density, and density by diameter class was determined for each species using the procedure outlined by Ebinger (1982). The importance value (IV) for each species was then calculated to provide a better basis for comparison of the various species in the forest areas studied. As used here the determination of the IV follows the procedure outlined by McIntosh (1957) and later Boggess (1964) in which the IV is the sum of the relative frequency, relative density, and relative dominance. The nomenclature used follows Mohlenbrock (1975).

RESULTS

An analysis of the aerial photographs of each section (Table 1) show that the counties in extreme southern Illinois (Alexander, Jackson, and Union) are for the most part heavily forested (74%-98%), have relatively small amounts of fields

and cultivated land (2%-26%), average 8.3 km of forest edge, 1.3 km of roads, and 2.5 occupied dwellings. In contrast, the sections in Calhoun County located in west-central Illinois, are less heavily forested (63%-81%), have extensive areas of non-forested land (19%-37%), average 77.6 km of forest edge, 2.6 km of roads, and 5 occupied dwellings.

Of the forest areas studied in each section, 10 are upland sites, composed primarily of ridges and narrow valleys. White oak (*Quercus alba*) is found in all of these forests, and in most is the leading dominant with an IV from between 23.2 and 102.3, averaging 64.0 and with an average basis area of 5.2 m^2/ha. Red oak (*Q. rubra*), black oak (*Q. velutina*), and occasionally yellow chestnut oak (*Q. muhlenbergii*) are commonly associated with white oak, and this species group generally dominated these upland forest sites. Hickories are also common components of these upland sites with an IV range of 21.9 to 80.5, averaging 54.2. These species include shagbark hickory (*Carya ovata*), mockernut hickory (*C. tomentosa*), bitternut hickory (*C. cordiformis*), and occasionally pignut hickory (*C. glabra*). Two species that contribute extensively to the understory are sugar maple (*Acer saccharum*) with an IV range of 10.6 to 90.6, and flowering dogwood (*Cornus florida*) with an IV range of 9.1 to 51.9. Over 75% of the sugar maple and 98% of the flowering dogwood are in the 1-2 dm diameter class. Other tree species encountered are tulip tree (*Liriodendron trulipifera*), sassafras (*Sassafras albidum*), white ash (*Fraxinus americana*), sour gum (*Nyssa sylvatica*), beech (*Fagus grandifolia*), and slippery elm (*Ulmus rubra*).

One forest area sampled in Jackson County, located near the Turkey Bayou Recreation Area, occurs in a lowland area. Overcup oak (*Quercus lyrata*) with an IV of 53.4 is the dominant tree species in the larger size classes. Other oak species include Shumard's oak (*Q. shumardii*), pin oak (*Q. palustris*), cherry-bark oak (*Q. pagodaefolia*), and bur oak (*Q. macrocarpa*). The oaks have a combined IV of 150.7. American elm (*Ulmus americana*) and sweet gum (*Liquidambar styraciflua*) account for nearly all of the individuals in the 1-2 dm diameter class of this forest. Sharbark hickory and kingnut hickory (*Carya laciniosa*), with a combined IV of 37.4, are the only hickory species encountered.

DISCUSSION

All of the sections studied in extreme southern Illinois are located in the Ozark, Shawnee Hills, and Lower Mississippi River Bottomlands Natural Division (Schwegman, 1973) which are part of the eastern deciduous oak-hickory forest. Hendricks (1969) stated that this area still contains the physical and biotic conditions suited to the Eastern Wild Turkey. A description of the study area would read very similar to Wheeler's (1948) description of ideal turkey habitat: "a well watered, forested area that is composed of a variety of timber types of which 50% is hardwoods (one half of which is oak), that is broken by well dispersed forested clearings that support rank growth of native grasses, legumes, and plants producing succulent fruits."

The present study suggests that the best habitat for wild turkeys in Illinois are forested areas in which oaks and hickories are the dominant overstory. In nearly all forests sampled oaks and hickories together account for more than 50% (IV of 150 or above) of the tree species present. Also, in most sections sampled, agricultural fields and forest openings are in close proximity. These canopy open-

ings provide food plants, breeding territories, nesting and brooding areas, and loafing grounds (Holbrook and Lewis, 1967). The increased edge effects created by the interspersion of forest and agricultural fields allows the intrusion of potential food plants into the mature forested areas. Lindzey (1967) noted that the birds prefer situations at the forest edge where suitable forest habitat is at hand.

Originally it was thought that the only acceptable turkey habitat was large unbroken tracts of mature timber, but now the birds are found in a variety of situations from virgin forest to late sapling stage hardwoods and even in woodlots (Dellinger, 1967). Loomis (1978) stated that wild turkeys are capable of surviving on relatively small tracts of timber if these woodlots are connected by narrow strips of woods or brushy draws not more than one fourth of a mile long. This more open habitat is typical of that found in Calhoun County, located in the Middle Mississippi Border Natural Division of west-central Illinois (Schwegman, 1973). Here the sections lack the extensive forests, more open fields, cultivated land, and orchards occur, and there is a relatively large amount of forest edge. This further indicated that the Eastern Wild Turkey, though originally a bird of extensive forest, is well adapted to more open agricultural areas with the associated increased edge.

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Table 1. General habitat of the kill areas and the composition of a representative forest of each kill areas in Illinois counties with high concentrations of turkeys.

SECTIONS STUDIED	GENERAL HABITAT OF KILL AREA						REPRESENTATIVE FOREST STUDIED IN KILL AREA							
	km of roads	km of edge	dwellings	% forest	% field	% orchard	Basal Area (m^2/ha)	Stem/ha	IV *Quercus spp.*	IV *Carya spp.*	Number of trees per ha by diameter class (dm) 1-2	2-3	3-4	4+
Alexander County														
Sec 14 T14S R2W	1.2	2.4	0	98	2	0	18.8	3	186.6	72.6	140	84	72	24
Sec 23 T14S R2W	2.0	4.0	0	96	4	0	24.2	332	213.9	21.9	132	52	88	60
Sec 31 T14S R2W	2.0	36.8	1	83	17	0	23.0	292	160.2	51.3	132	52	48	60
Calhoun County														
Sec 16 T10S R2W	2.8	76.8	8	63	31	6	18.4	388	123.6	34.2	256	48	52	32
Sec 20 T9S R2W	3.2	114.2	4	64	29	7	19.0	364	121.5	47.1	196	72	68	28
Sec 27 T11S R2W	1.9	41.9	3	81	17	2	21.3	328	82.9	27.4	160	52	80	36
Jackson County														
Sec 34 T10S R3W	1.6	4.5	10	98	2	0	20.0	340	154.3	75.5	168	56	60	56
Sec 2 T10S R3W	.8	5.7	0	95	5	0	20.6	412	150.7	37.4	232	64	36	80
Union County														
Sec 14 T11S R3W	1.2	2.4	1	92	8	0	22.0	352	143.1	80.5	148	104	48	52
Sec 4 T13S R2W	0	1.0	0	96	4	0	29.9	304	103.0	76.4	104	60	88	52
Sec 15 T12S R2W	1.8	9.7	8	74	26	0	20.6	360	190.4	55.1	152	84	64	60

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SURFACE FEATURES OF *TETRAHYMENA ROSTRATA* AS VIEWED WITH SCANNING ELECTRON MICROSCOPY

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ABSTRACT

Trophonts and cysts of *Tetrahymena rostrata* (ANL) were examined with scanning electron microscopy in order to reveal minute surface morphological features for the first time in this species. Measurements of surface organelles from electron micrographs provided the following average values: ciliary widths (0.31 μm), ciliary lengths (4.7μm), alveolar pit diameters (3.7μm), buccal overture (6.7 $\times$ 5.4μm). The number of ciliary units in a typical somatic kinety was 40, while that of a post-oral kinety was 30. The external wall of encysted individuals is irregular and featureless; the average diameter of cysts was 24μm.

Morphological descriptions of stages in the life cycle of the hymenostome ciliate, *Tetrahymena rostrata* (Kahl, 1926; Corliss, 1952); have been confimed so far to investigations with the light microscope (Stout, 1954; Corliss, 1973) or to the analysis of thin-sectioned material viewed with the transmission electron microscope (Zebrun et al., 1967; McArdle et al., 1980). Although methods for the preparation of ciliate protozoans for scanning electron microscopy have been available for some time (Small and Marszalek, 1969) there have not been any previously published reports on the external features of *T. rostrata* using this informative and valuable method. This investigation undertakes to provide information on the surface features of the cortex of trophic organisms and on the cyst wall of encysted representatives of this polymorphic species (Corliss, 1973).

MATERIALS AND METHODS

The trophonts (feeding stages) and cysts used in this study were isolated by the author from moss plants growing on the grounds of the Argonne National Laboratory (ANL) and identified as *Tetrahymena rostrata*. Some subcultures were rendered axenic with antibiotics for laboratory culture (Holz and Thomp-

son, 1955) and maintained on an enriched proteosepeptone broth medium (Dobra et al., 1980). Other subcultures were periodically administered raw beefsteak while being cultured in 0.01 % Knop's solution in glass three-hole depression slides in a humidity chamber. Between periods of feeding, the lack of food would induce cyst-formation (McArdle et al., 1980). Organisms were withdrawn from these cultures at appropriate intervals of their life cycle and fixed according to the methods described by Small and Marszalek (1969). Following fixation, they were washed several times in distilled water before being dropped by pipette onto the surface of an aluminum "boat" floating on liquid nitrogen. The frozen droplets that formed were transferred to a metal stub and subjected to drying by sublimation in a Baltzer vacuum evaporator for approximately 12 hours. Following drying the specimens were gold-coated and examined with a Cambridge Stereoscan Mark IIA scanning electron microscope made available by the Division of Biological and Medical Research of ANL.

RESULTS AND DISCUSSION

The surface features of *Tetrahymena rostrata* strain ANL as revealed by SEM are pictured in Figures 1-5. Trophonts (feeding stages) of the ciliate are depicted in Figs. 1-3 and 5. Fig. 1 shows the ventral surface of the typical body form of a trophont (49μm long $\times$ 26μm wide). The cilia on such forms are characteristically arranged in regular rows (kineties) extending from the subapical pole of the cell to the subterminal pole. The cilia vary only slightly in width in this preparation (0.27-0.36μm) and are generally rather uniform in length, with a range of from 3.6 - 6.1μm (average 4.7μm; n = 10). The cilia in Fig. 3 can be seen to emerge on the surface of the ciliate from shallow, ovoid-shaped depressions that have an average diameter of 3.7 μm (n = 26). On favorably oriented specimens the number of individual cilia in a single kinetal row can be counted. For example on one such organism, the exact number of cilia in a full anterior-posterior kinety was 40, while the shorter, post-oral kinety that extends from the posterior border of the buccal overture to the sub-terminal pole was 30 ciliary units. The buccal overture is ovoid in shape (see Fig. 2), being slightly longer (6.7μm) than it is wide (5.4μm). Details of the interior of this cavity are obscured by the dense packing of the cilia comprising the undulating membrane.

Several "resting" or "resistant" cysts are shown in Fig. 4. These generally ovoid and elliptical-shaped forms were obtained from a "bacterized meat" culture. They show the characteristic aggregation that occurs prior to encystment when small groups of trophont ciliates congregate together while secreting a cystic wall. The finished wall is an un-ornamented, irregular sheet of secreted mucus completely enclosing the organism. In this figure the cyst walls are covered with bacterial organisms that were associated with them in the medium at the time of fixation. The measured diameters of the cysts varied from 22-27 μm (with an average value of 24μm).

The posterior pole of a trophont is illustrated in Fig. 5. The kineties converge toward the posterior end, but stop just short of it. The membranous area at the posterior pole possesses a single (sometimes double) cilium that has been termed a "caudal cilium" (Corliss, 1973). In this specimen it has been sheared off close to the surface membrane and is seen only as a short stub.

The results of this SEM investigation essentially corroborate the observations made to date on *T. rostrata* by both light microscopy and transmission electron microscopy. In addition, it contributes new information on the length and width of individual cilia and on the number of discrete ciliary units in somatic and post-oral kineties. The surface features of bacterized cysts are shown for the first time as is the precise location of the "caudal" cilium at the posterior pole of the organism. These provide a basis for comparison with the surface features of other tetrahymenid species.

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Fig. 1. Ventral view of a trophont of *T. rostrata* showing the subterminal position of the buccal overture at the anterior end and the holotrichous arrangement of the ciliary rows. The opaque material at the periphery of the organism is likely agglomerated mucoid material secreted by the organism's mucocyst organelles. The scale bar indicates 10 μm.

Fig. 2. The buccal overture is depicted at higher magnification. It shows the position of the undulating membrane (um) on the organism's right side of the buccal opening. The oral area is surrounded by somatic ciliation. The scale bar indicates 1 μm.

Fig. 3. A partially de-ciliated surface of a trophont. The cilia that remain (arrow) are relatively uniform in size and emerge from aveolar depressions in the cortex. The scale bar indicated 1 μm.

Fig. 4. Four encysted individuals of *T. rostrata*. The secreted cyst wall is uneven and irregular in its appearance but conforms to the general shape of the organism within. The small, light-colored rods on the surface are environmental bacteria adhering to the outer face of the cyst wall. The scale bar represents 10 μm.

Fig. 5. A view of the posterior end of a trophont showing the convergence of the ciliary rows and the location of a characteristic polar cilium (arrow). The scale bar denotes 10 μm.

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SPIRIFERELLINA LATA LANE IN THE UPPERMOST CHESTERIAN IN THE BIRD SPRING GROUP AT ARROW CANYON, CLARK COUNTY, NEVADA.

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ABSTRACT

Spiriferellina lata Lane ranges from the uppermost Indian Springs Formation to at least the top of the Mississippian in the Bird Spring Group at Arrow Canyon, Clark County, Nevada.

INTRODUCTION

This study was undertaken to document occurence of *Spiriferellina lata* in the uppermost Chesterian at Arrow Canyon, Clark County, Nevada. *S. lata* is a member of the distinctive fauna of the Chesterian-Morrowan transition in the southern part of the Cordilleran miogeosyncline. Determination of its range of morphologic variation and its precise Chesterian occurences at Arrow Canyon is significant because the Arrow Canyon section is an important reference standard for Carboniferous correlations in western North America.

PRIOR INVESTIGATIONS

The Arrow Canyon sequence has been subjected to several statigraphic investigations, several of which, have included consideration of *S. lata*. Coogan (1962, 1964) reported this brachiopod as *Reticulariina spinosa* in his unit 41 at Arrow Canyon. Langenheim and Langenheim (1965) cite occurence of *Punctospirifer campestris* in their unit 6 in a faunal list of fossils collected in reconnaisance of the Bird Spring Group at Arrow Canyon. It is the same brachiopod that is under investigation in this report. Webster (1969) provided a conodont zonation for the Bird Spring Group at Arrow Canyon and also reports *S. lata* as *Spiriferellina* sp. in his units 22, 24, 25, 26, 27 at our study locality.

The entire Bird Spring Group in Arrow Canyon was measured by Amoco Production Corporation. Their stratigraphic bench marks, placed at intervals of 1.5 meters of thickness, are used as standards of measurement in this report.

LOCATION

Arrow Canyon is in the E 1/2, section 11, and S 1/2, section 12, T. 14 S., and R. 64 E., and SW 1/4, section 7, T. 14 S., R. 65 E., Clark County, Nevada. The canyon is reached by proceeding 11 miles northwest of Glendale, Nevada, on Nevada Route 168, turning left on a secondary road and continuing for 0.4 miles, at this point turn right on a jeep road at south margin of the wash. The collecting locality is about a mile up the wash just below the upper gorge of Arrow Canyon proper. The specimens were obtained from the east cliff face of an east-west trending strike valley underlying the Indian Springs Group, about 200 yards north of the drainage line in Arrow Canyon (Fig 1).

PROCEDURES

Field work for this report was done during the first two weeks in January, 1984. After locating previously determined system and series boundaries and the Amoco benchmarks, samples were taken from the units and etched in a 10% solution of commercial grade hydrochloric acid.

LITHOSTRATIGRAPHY

The 100 feet of strata just below the Mississippian-Pennsylvanian boundary at Arrow Canyon are mostly grey, massive to thick-bedded limestone (Figs. 2,3). Several prominent brachiopod biostromes occur within these units. Fossils are mostly silicified and well preserved. The base of the column rests is at the top of the prodominantly shaly part of the Indian Springs Formation and is composed of interbedded shale and buff colored limestone, also belonging to the Indian Springs Formation. The succeeding grey, massive, medium-grained limestone is part of the Bird Spring Bsc unit (Langeheim, R.L., 1962). The Mississippian-Pennsylvanian boundary is at the base of the limestone conglomerate, unit 29, as defined by Webster (Webster and Lane, 1967, Webster, 1969, Webster and Langenheim, 1979). This is succeeded by a shaly unit, unit 30, and a massive, silty, cross-bedded limestone unit, unit 31A.

Lane, Brenckle, and West (1983 a,b) have suggested several possible alternate positions for the Mississippian-Pennsylvanian boundary, ranging from 12.5 meters below the conglomerate to 12.35 meters above the conglomerate.

Spiriferellina lata occurs in all of the units shown on the column except units 30 A and C, 29, 23 and 21. The specimens which possess spines are from unit 24E occurring with specimens lacking spines.

DESCRIPTION OF THE MEASURED SECTION

Unit	Thickness	Description
31B	+4.3ft 1.30m	Sandy limestone, grey, weathers tan to rust, massive, small scale cross-bedding.

Unit	Thickness	Description
31A	5.7ft 1.75m	Sandy limestone, light grey, weathers rust brown, massive, silicified cross-bedding approximately 0.3m high by 1m long.
30C	3.9ft 1.19m	Shale, light grey, weathers yellow, blocky, non-resistant, 3" arenaceous stringers at base.
30B	0.3ft 0.09m	Limestone, grey, stained yellow, 2" bedding, contains some chert.
30A	0.2ft 0.06m	Shale, light grey, stained yellow, thin-bedded, non-resistant.
29	1.0ft .31m	Limestone conglomerate, chocolate brown, weathers same, limestone clasts as much as 1.5", constant thickness.
28B	1.0ft .31m	Limestone, light grey, weathers same, thin discontinuous bedding, calcite filled fractures.
28A	4.2ft 1.28m	Limestone, light grey, weathers same, thick-bedded to massive, calcite filled fractures, bioclastic.
27	3.3ft 1.01m	Shaly limestone, light grey, weathers same, thin-bedded, calcite filled fractures, earthy smell, some brachiopods.
26F	1.0ft 0.31m	Limestone, light grey, weathers same, medium- to thin-bedded, calcite filled fractures.
26E	1.0ft 0.31m	Limestone, light grey, weathers same, thin-bedded, calcite filled fractures, some brachiopods.
26D	14.7ft 4.39m	Limestone, light grey, weathers same, thick-bedded to massive, calcite filled fractures, discontinuous chert beds, silicified brachiopod biostromes, *Spiriferellina* abundant, cliff former.
26C	0.9ft .28m	Limy shale, grey, weathers light grey, poorly bedded, fossiliferous.
26B	23.7ft 7.22m	Limestone, light grey, weathers same, massive to thick-bedded, chert beds, brachiopod biostrome, cliff former.
26A	1.8ft 0.55m	Limestone, light grey, weathers same, medium- to thin-bedded at bottom, coarse-grained, *Spiriferillina* biostrome.
25	0.6ft 0.18m	Shale, light grey, weathers same, non-resistant, calcareous.
24E	2.6ft 0.79m	Limestone, light grey, weathers rust, medium-bedded, bioclastic, fine-grained.

Unit	Thickness	Description
24D	0.1ft 0.03m	Shale, light grey, weathers same, non-resistant.
24C	2.7ft 0.82m	Limestone, light grey, weathers same, thick-bedded, fine-grained, some cross-bedding, bioclastic.
24B	1.2ft 0.37m	Shaly limestone, light grey, weathers same, fine-bedded, cross-bedded.
24A	6.8ft 2.12m	Limestone, light grey, weathers rust, thick-bedded to massive, abundant fossils, crypto-crystalline.
23	2.0ft 0.61m	Limestone, buff, weathers same, non-resistant, bioclastic.
22B	1.6ft 0.49m	Shale, green to red, weathers red, non-resistant, blocky.
22A	2.9ft 0.88m	Limestone, grey to brown, weathers rust, medium- to thick-bedded, cryptocrystalline with calcite megacrysts in cracks, abundant spirifers at top, bench former.
21	+0.5ft 0.15m	Shale, light green, weathers same, non-resistant, blocky.

SYSTEMATICS

Higher systematics are from The Treatise of Invertebrate Paleontology, Part H, Brachiopoda (Moore (ed.), 1969). The concept of *Spiriferellina* is based on Campbell's redescription of the genotypes of *Spiriferellina*, *Punctospirifer*, and *Reticularina*. Type specimens are in the collection of the Department of Geology, University of Illinois, Urbana, Illinois.

Phylum Brachiopoda Dumeril, 1806
Class Articulata Huxley, 1869
Order Spiriferida Waagen, 1883
Sudorder Spiriferidina Waagen, 1883
Superfamily Spiriferinacea Davidson, 1884
Family Spiriferinidae Davidson, 1884
Genus *Spiriferellina* Fredricks, 1918
Spiriferellina lata Lane, 1963

Figs. 4-23

Spiriferellina lata, Lane, 1963, pl. 45 fig. 1, 2, 4-14, p389.
Punctospirifer campestris, (White), Langenheim, 1964, pl. 6, no. 9, p93-94, *pars*, specimens from locations b4972; 5199.

Shell ranges from small to medium size. The largest are 27mm wide by 20mm long and the smallest 6mm wide and 5mm in length. The shell is biconvex and generally semi circular in outline. Some specimens are slightly extended on the hingeline. Irregular shapes also occur.

The greatest width is at or within 3mm of the hingeline. The shell is coarsely punctate and granular. Strong imbricate growth lamellae ornament both valves, becoming more prominent and more widely spaced at the anterior margin, with spacing as wide as 7 per cm. Some shells also have a row of spines in the axis of the sulcus and on the axis of the fold. Scattered spines also exist on the shell surface. Only six specimens among an estimated 50, retained their spines. Table 1 indicates the sizes of four specimens which were articulated.

The pedicle valve is moderately convex transversely and horizontally and is more convex toward the anterior and slightly more convex towards the sides. The interarea is aspacline and about 1/3 as high as wide. The beak is incurved. The umbo ranges from strongly inflated to moderately inflated. Four simple angular plicae are present, the three closest to the sulcus being strongly developed. A fourth weak plication is on the hingeline of some specimens. The outer plicae do not originate at the beak. The valve interior contains a septum ranging from 1/3 of the length of the shell to the entire length of the shell.

The brachial valve is smaller and less convex than the pedicle valve. It is longitudinally semiovate. Tranversly, the flanks are increasingly convex. The beak is small. The brachial valve is orthocline and lacks an interarea. In most specimens, the medial plication is distinctly higher than the lateral plicae but it is about the same height in a few individuals. Otherwise, the plicae resemble those of the pedicle valve. The cardinal process is very small and subovate in outline. The inner hinge plates are triangular, where meeting the cardinal process. They form a "V". The outer hinge plates are subtriangular meeting the shell at a right angle. Thin dental plates extend along the floor of the valve for approximately the shell length.

Hypotypes A6353-A6355, A6359, A6360 collected from Unit 26D between A51 and A52; A6356 collected from Unit 26D between A52 and A53; A6357 collected from Unit 24C between A44 and A45; and A6358 collected from Unit 26A between A45 and A46. Also, approximately 75 additional specimens were available for study.

DISCUSSION AND CONCLUSIONS

The Arrow Canyon specimens were assigned to *Spiriferellina* instead of *Punctospirifer* and *Reticulariina* after comparison with the genotypes as redescribed by Campbell (1959). *Spiriferellina* spp. are distinguished by 4-6 low, angular plicae, imbricate growth lamellae and micro-ornamentation of fine granules. *Punctospirifer* spp. tend to have more, but less angular plicae; and a wider and more rounded sulcus. *Reticulariina* spp. are distinguished by large, elliptical, hollow spines or spine scars. Most of the Arrow Canyon specimens lack large elliptical spines characteristic of most *Reticulariina*. Nevada spinose specimens, however, slightly resemble *Reticulariina spinosa* (Norwood and Pratten, 1855), but the spines are too small and too numerous for assignment to *Reticulariina*. The plicae are too few, too angular, and the sulcus too wide for assignment to *Punctospirifer*.

S. lata was first described in Clark County, Nevada by N.G. Lane (1963). His described materials closely resemble some of the Arrow Canyon specimens. The Arrow Canyon specimens differ, however, in that some have spines, longer or shorter median septa or an outline that is either more or less alate. Based upon faunal associations, Lane (1963) concluded that *S. lata* was Morrowan. Lane's

material, however, appears to have been collected from limestone directly above the shaly part of the Indian Springs Formation of the Bird Spring Group as are the Arrow Canyon specimens. These rocks, now are placed in the uppermost Chesterian (Webster, 1969). In addition, the faunal association described by Lane in the Spring Mountains is the same as that of the Arrow Canyon spirifer. Thus it appears that morphologic differences between the two collections reflect individual diversity.

The Arrow Canyon specimens first were assigned to *Punctospirifer campestris* (Langenheim, V.A.M., 1964; Langenheim and Langenheim, 1965) and were considered conspecific with the *Punctospirifer campestris* described by B.O. Lane (1962). Those from unit 6 in her measured section are part of the same population described in this work but were collected at the foot of the slope on the north wall of the canyon a few hundred feet south of our collecting locality. Her specimens from unit 33 are too few and too poorly preserved for careful comparison with my collection. *S. lata* from Langenheim's unit 6 and our collection differ from *Punctospirifer campestris* (White) described by Lane which have twice as many lateral plicae as the Arrow Canyon specimens as well as a markedly wider sulcus.

Abundant *Spiriferellina lata* Lane are a prominent component of the latest Chesterian fauna of the Indian Springs Formation and BSc formation of the Bird Spring Group at Arrow Canyon. Morphologic diversity in the collections from Arrow Canyon transcends that described by Lane (1963) at Lee Canyon.

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_____. 1877. Reports upon the invertebrate fossils collected in portions of Nevada, Utah, Colorado, New Mexico, and Arizona by parties of the expeditions of 1871, 1872, 1873, and 1874, Report of the expedition of geographical and geological surveys out of Nevada, Utah, Colorado, New Mexico, and Arizona: United States Army Engineer Department, Washington, V. 4, pt. 1, 219p.

Table 1. Dimensions of articulated *Spiriferellina lata*.

Specimen	Width	Length	Height
A6359	6.2mm	4.5mm	3.8mm
A6357	13.9mm	9.5mm	7.3mm
A6353	21.9mm	17.2mm	16.6mm
A6360	15.0mm	13.4mm	10.2mm

EXPLANATION OF FIGURES

Fig. 1. Location Map of Arrow Canyon.
Fig. 2. Upper part of the columnar section.

Fig. 3. Lower part of the columnar section.

Figs. 4-8. Hypotype A6353, X1.

4. Dorsal exterior
5. Ventral exterior
6. Posterior
7. Anterior
8. Lateral

Figs. 9-11. Hypotype A6354, X1, alate pedicle valve.

9. Exterior
10. Interior
11. Lateral

Fig. 12. Hypotype A6355, X1, pedicle valve rounded posterior.

Figs. 13-15. Hypotype A6356, X1, brachial valve.

13. Exterior
14. Interior
15. Lateral

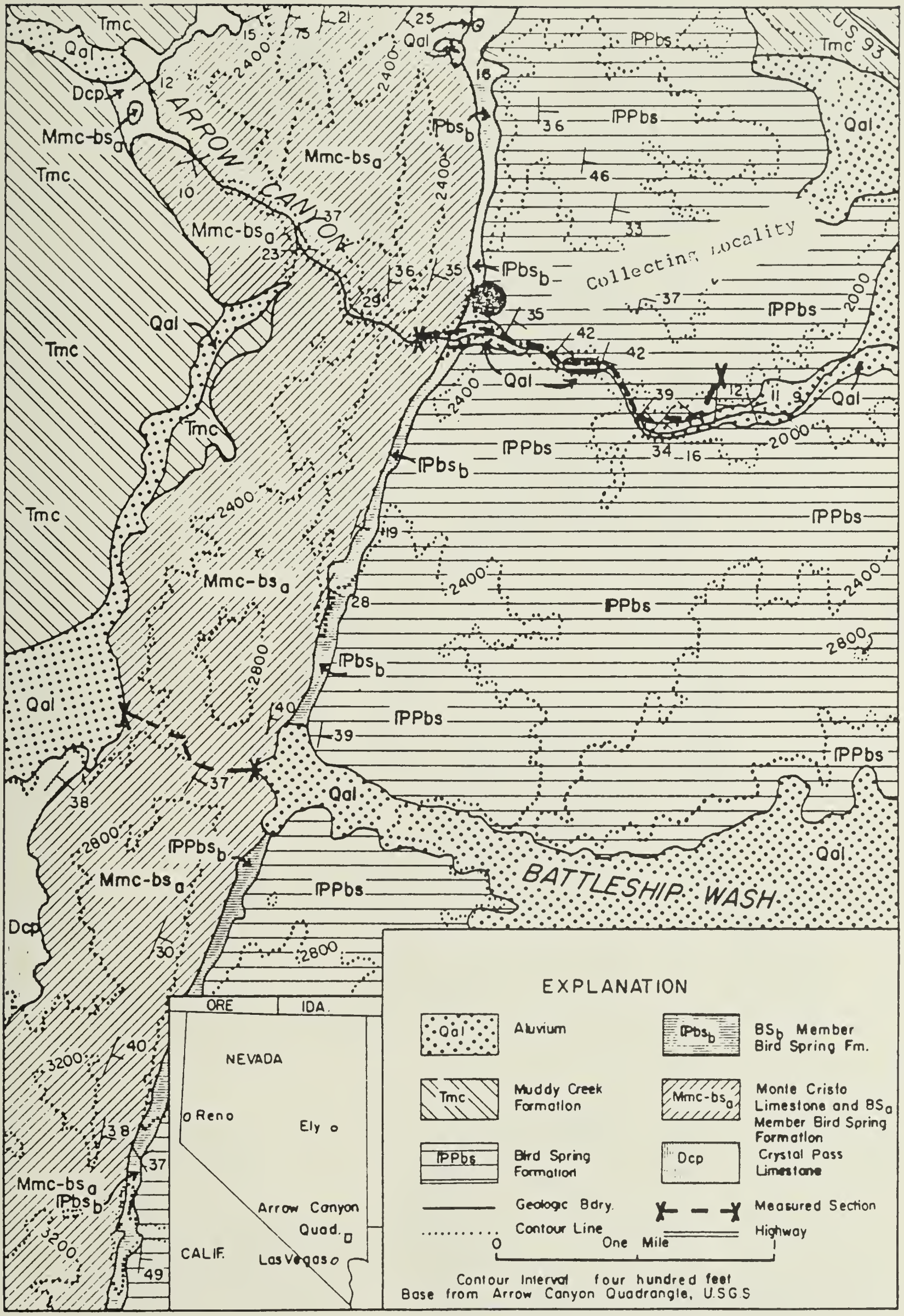
Figs. 16-20. Hypotype A6357, *Spiriferellina lata* with preserved spines.

16. Pedicle exterior X4
17. Pedicle exterior X2
18. Pedicle interior with short septum X2
19. Brachial exterior X2
20. Brachial interior X2

Fig. 21. View of micro-ornamentation of hypotype A6354, X6.

Fig. 22-23. Hypotype A6358, X1 pedicle valve with long septum.

22. Interior
23. Exterior


Tmc
Qal
Dcp
Mmc-bs$_a$
ARROW CANYON
Pbs$_b$
IPPbs
US 93
Collecting Locality
BATTLESHIP WASH
EXPLANATION
Aluvium
BS$_b$ Member Bird Spring Fm.
Muddy Creek Formation
Monte Cristo Limestone and BS$_a$ Member Bird Spring Formation
Bird Spring Formation
Crystal Pass Limestone
Geologic Bdry.
Measured Section
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Highway
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Base from Arrow Canyon Quadrangle, U.S.G.S
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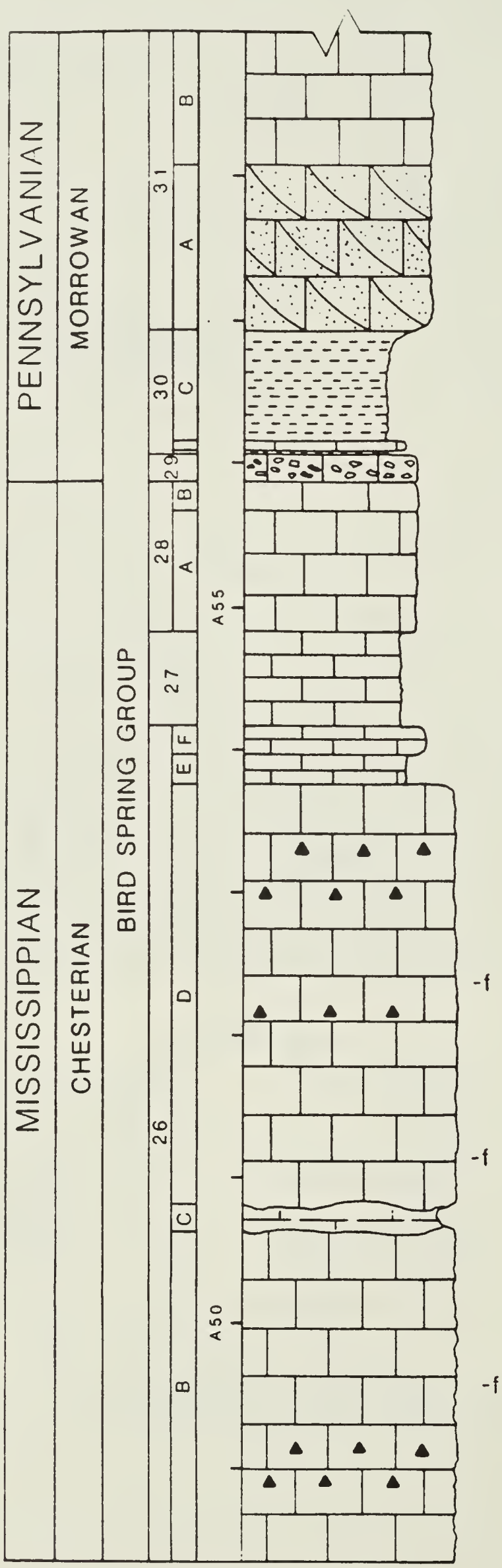
Arrow Canyon Quad.
CALIF.
Las Vegas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Webster
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SCALE
feet
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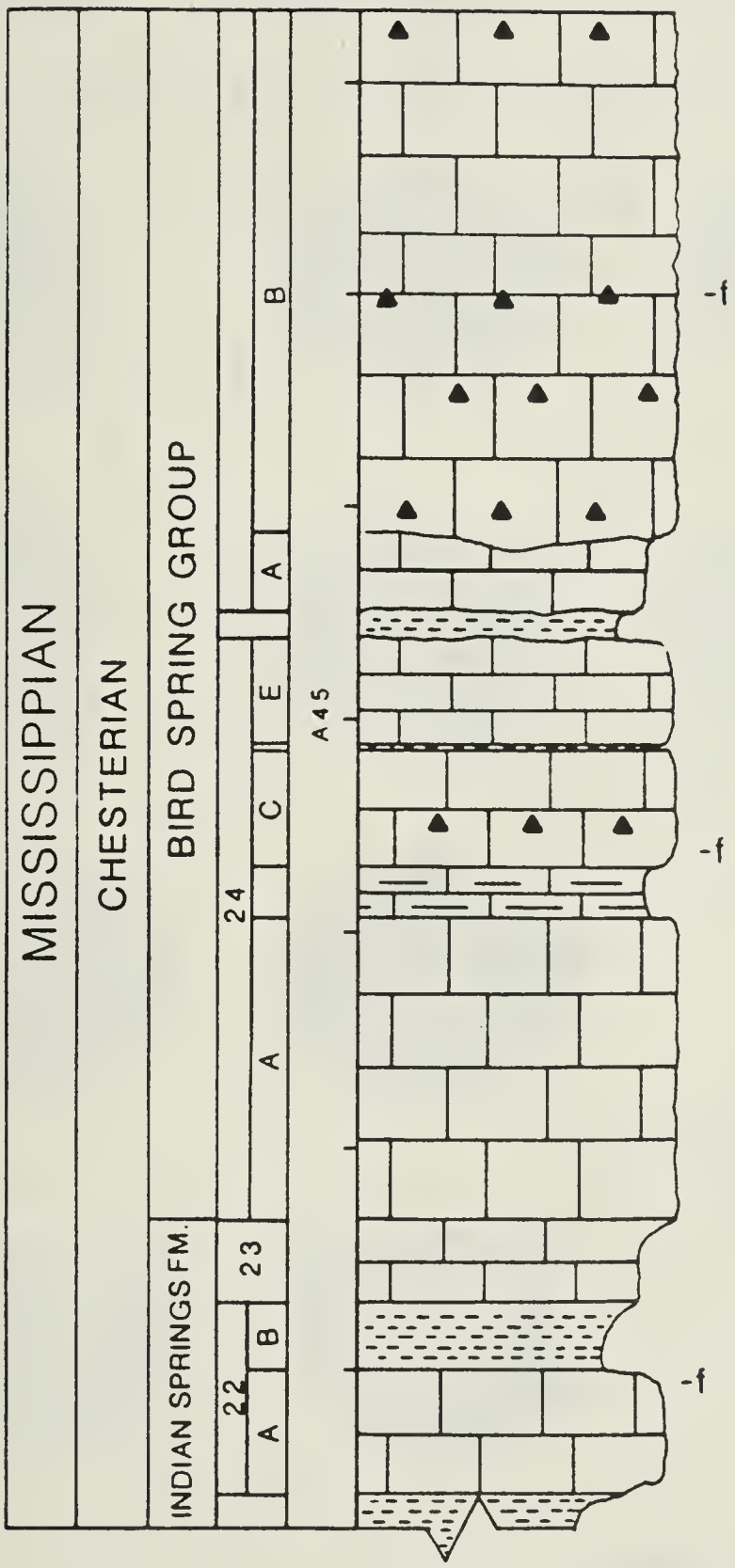

EXPLANTION

LIMESTONE, THICK BEDDED TO

LIMESTONE, MEDIUM BEDDED

LIMESTONE, THIN BEDDED

SANDY LIMESTONE, CROSSBEDDED

CONGLOMERATE LIMESTONE

SHALE

CALCAREOUS SHALE

SHALEY LIMESTONE

▲ CHERT

-f BRACHIOPOD BIOSTROME

SCALE

feet	meters
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5

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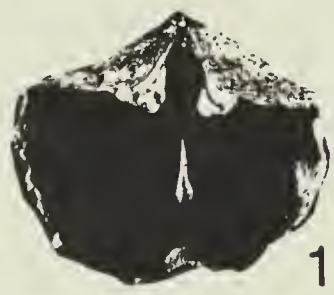
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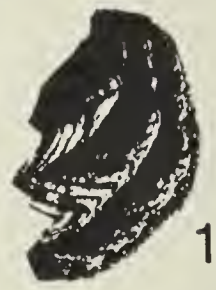
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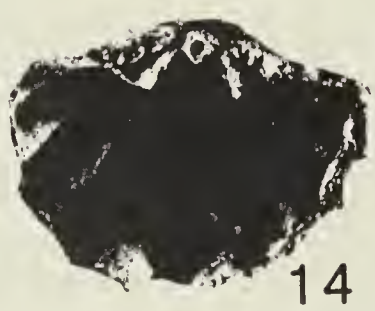
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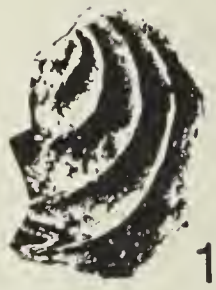
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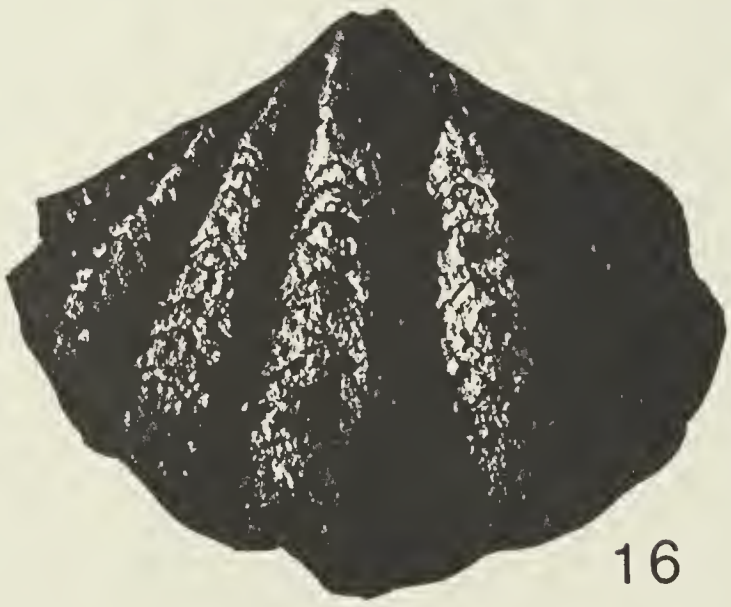
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(1984), Volume 77, 3 and 4, pp. 219-228

VARIATION IN THE RELATIONSHIP BETWEEN CORN YIELD AND CLIMATE IN A SAMPLE OF COUNTIES IN ILLINOIS 1951-1980

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ABSTRACT

Building off an earlier study, the relationship between corn yield and weather variables in ten counties in Illinois from 1951 to 1980 is studied. First differences in corn yield were computed and used to identify a change in the pattern of yield variability occurring after 1965-66. For each county, the time series of average per acre yield of corn was regressed in a stepwise fashion against weather variables using an additive model. From the regression results, a coefficient of variation was calculated showing the amount variation in the corn yield explained by the weather variables. In comparison to similar coefficients derived from an earlier study, the results of the present study indicate a marked increase in the amount of yield variability attributed to weather. Consequently, farmers are dealing with greater weather induced yield variability in corn than previously.

INTRODUCTION

Farmers operate in an uncertain world in which the impact of their managerial decisions on net farm income is affected by many factors beyond their control. Such factors include changes in commodity prices, input costs, and crop yield. In this study, we take up an investigation initially reported by Changnon and Neill in 1967. In that study they used estimates of the relationship between

corn yield and weather variables to delineate regions of Illinois with similar weather dependent, corn yield variability. The significance of such research derives from the possibility of farmers adopting managerial strategies to lessen the adverse impacts of climatically induced yield variability as well as the needs of actuaries working for crop insurance programs to develop estimates of spatial yield variability.

Since the completion of the earlier study by Changnon and Neill, evidence has accumulated indicating change in corn yield variability. The corn yields in Illinois during the 1951-80 period seem to show great year to year variability, especially since 1965 (fig. 1). This variability is further highlighted when the first differences in the yearly yields are plotted (fig. 2). (A first difference is the difference in the observations for year i and year i - 1 in a time series. [Tintner 1940; Carter and Dean, 1960]). Additionally, a number of investigators have hypothesized that the nature of the variability of key climatic parameters has changed as well (e.g. Dyer 1978; Skaggs, 1978 and Thompson, 1975). The question that arises from these observations is, 'Is the increased yield variability in Illinois during the period 1951 through 1980 weather induced?'

If crop yield variability has increased in response to increased climatic variability, then application of the same crop climate model to two different time periods should show that weather variables for the period increased climatic variability account for a larger share in the explanation of yield variability. To test this hypothesis we repeated a portion of the Changnon and Neill study using a time series of yield and climatic data partially overlapping the data of the earlier study, i.e., 1951 through 1980 vs. 1930 through 1963. County data for one sample county from each of the Crop Reporting Districts of Illinois were used. Due to local interest, Jackson County was also included.

MATERIALS AND METHOD

Data on the average per acre yield of corn and weather variables were collected from ten counties throughout Illinois. The data on yields were collected from the Illinois Cooperative Crop Reporting Service. The data on the climatic variables were collected from U.S. Weather Stations located in the respective counties and adjacent to them. The map in fig. 3 indicates the counties studies as well as the weather stations from which data were obtained. The weather variables used in the analysis paralleled those used by Changnon and Neill: mean temperatures for the months of May, June, July and August; total rainfall for June, July and August and preseason precipitation (September through May).

In their study Changnon and Neill used two sets of dummy numbers following Thompson, 1966; one set representing the general trend of technology in the 1930-57 period and the second set expressing an accelerated technology effect since 1958. Instead of using two sets, in this study one set of dummy variables was used with a uniform rate of change till 1960 and an accelerated rate of change in the later years; both rates follow the trend in fertilizer use for Illinois.

Changnon and Neill used all the 102 counties in their study. In the present study, one sample county was chosen from each Crop Reporting District; the

choice was based on availability of climatic data for the period of study. The counties included in the study and their corresponding Crop Reporting Districts in parenthesis are: McHenry (Northeast), Bureau (Northwest), McDonough (West), McLean (Central), Vermillion (East), Sangamon (West Southwest), Shelby (East Southeast), Wayne (Southeast) and St. Clair and Jackson (Southwest).

For each county, the time series of average per acre yield was regressed in a stepwise fashion against the weather variables using an additive model. The exact functional forms used in the earlier study were unreported and unavailable from the authors. For each regression model, relevant statistics were calculated using programs contained in Statistical Package for the Social Sciences (SPSS), e.g., R^2, $\bar{R}^2$, Durbin-Watson, standard errors of the estimated coefficients. In addition, we calculated the coefficient of variation used by Changnon and Neill to identify regions of the state with different degrees of weather dependent yield variability. The coefficient of variation is calculated as follows:

$$\text{Coefficient of Variation} = \frac{\sqrt{\text{Regression Mean Square}}}{\text{Mean Yield}}$$

As this coefficient of variation increases, it implies that more and more of the variation in the yield is explained by the variables included in the regression equation, in this case weather. The results from out analysis were then compared to the results of the earlier study using this coefficient of variation.

RESULTS AND DISCUSSION

Yield per acre was regressed on the eight weather variables previously used in the Changnon and Neill study. The results obtained from the present study are contained in table 1. The table indicates a number of interesting results, first across the counties studied there is a large amount of variation in the $\bar{R}^2$s and the $\bar{R}^2$s. The range in R^2 is from 0.26 for McDonough County in the West Crop Reporting District to 0.61 for St. Clair County in the Southwestern Crop Reporting District. The small $\bar{R}^2$s indicate a need to reduce the number of independent variables. This has been done in subsequent analyses. This need for a reduction in the number of independent variables is also indicated by the limited number of independent variables that have statistically significant estimated coefficients. The Durbin-Watson statistics indicate a potential problem with serial autocorrelation, in most cases the statistic falls into the indecisive range for the test. This indicates the need to look at a new functional form, e.g., log linear or some other curvilinear form, or the use of generalized least squares. Across the estimated models in table 1, we see that there is extensive variation in the size of the estimated coefficients for the same variable across counties as well as variation in sign.

For example, the sign of July temperature (JLT) is negative across all the sites indicating that as average July temperature increases, all else held constant, that

corn yields decline. However, the actual size of the estimated coefficient ranges from a low of −0.29 for McHenry County in the the Northeastern Crop Reporting District to a high of −6.79 in McLean County in the Central Crop Reporting District. Similarly for June temperature (JT) we find that the sign of the estimated coefficients is negative for all the sites except for McHenry County where it is positive and significant at the 10% level. Perhaps this is due to the fact that among the counties studied this county is located in the northernmost part of the state.

August precipitation (AP) is another example of variability in the estimated coefficients across the study counties. August precipitation is significant in Wayne, McHenry, Vermillion, St. Clair and Jackson Counties. Across the counties, August precipitation is positively related to yield except in McDonough County. In six of the sites we find that the positive effect of August precipitation is balanced by the negative effect of August temperature. Indeed, out next step is the development of a new variable capturing the joint effects of such variables.

Comparing the coefficients of variations from this study and the earlier one by Changnon and Neill (table 2), we find that for all the counties studied, there has been a significant increase in the amount of variability in corn yields attributed to the weather variables. Only for the case of Shelby County do we find that the new coefficient of variations is contained in the bounds reported by Changnon and Neill. For the other counties, there has been a marked increase, indicating the increased influence of weather variability on year to year yield variability. This can be taken as an indication of increased weather variability.

The weather events during the last 10-12 years suggest increased year to year variability compared to the years before. The Southern Leaf Blight during 1970, the early freeze during 1974 and the dry summer of 1980 caused large yield reductions. The 1960's, on the other hand, were generally favorable years for corn. Consequently, we can conclude that farmers in these areas are finding an increased portion of the variability in corn yields attributed to weather variation.

In the Changnon and Neill study additional regressions of both technology and weather factors with corn yields produced correlation coefficients above 0.88 in all counties. Table 3 shows the R^2s, $\bar{R}^2$s and Durbin Watson statisitics obtained in our updated study. The R^2s range from 0.77 for Wayne County (SE) to 0.91 for McHenry County (NE). The technology variable is significant for all the counties. July temperature is the most significant weather variable with the level of significance ranging between 1% and 10%. July precipitation is the next significant weather variable followed by August temperature and August precipitation. Six counties showed significant, estimated coefficient for July precipitation. Most of these counties are in the southern part of the state, e.g., Wayne (SE), St. Clair (SW), Shelby (ESE), Jackson (SW). The counties not in the southern part and showing a significant, estimated coefficient for July precipitation are McDonough (W) and McHenry (NE).

Similar observation can be made about August temperature. The counties with significant, estimated coefficients are Sangamon (WSW), Shelby (ESE), Jackson (SW) and Wayne (SE). The pattern agrees with the areas of high and low correlation found by Changnon and Neill. August precipitation does not show such regional differences; the counties with significant, estimated coefficients are

McHenry (NE), McDonough (W) and Wayne (SE). June temperatures show a significant effect on yield only in McHenry County whereas June precipitation shows significance for Wayne County (ESE) only. May temperature shows a significant positive relationship with yields at Sangamon (WSW) and Shelby (ESE) Counties. Although preseason precipitation shows a significant effect in McHenry (NE) and St. Clair (SW) Counties, the signs for the coefficients are opposite.

SUMMARY

Our analysis indicated that during the last thirty years there has been an increase in corn yield variability attributed to weather. This increase needs to be further verified by using other appropriate functional forms in the regression analysis. In addition, an effort must be made to move away from the use of monthly data and begin specifying weather variables that more closely approximating weather factors influencing yield throughout the growing season, i.e., a drought index, wet days and dry days, etc. Even given these limitations, the data indicate that farmers throughout Illinois have experienced greater variation in the yield of corn from weather factors than previously. This increase in variability influences the decisions farmers make with repect to crop management, marketing strategies, and on-farm investment. Consequently, farmers require strategies to help them minimize the negative effects of increased weather-dependent variability in corn yields.

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Academy of Sciences, Macomb, Illinois
April 1983

Table 1. Results of Regressing Corn Yield Against Weather Variables for Ten Illinois Counties: 1951-1980.

		Independent Variables, Estimated Coefficients & Standard Errors								Regression Statistics		
Area & County	Intercept	MT	JT	JLT	AT	JNP	JLP	AP	SNP	R^2	$\bar{R}^2$	DW
Bureau NW	450.73	− 0.23 (3.37)	− 1.21 (1.55)	− 2.67 (2.11)	− 0.83 (1.60)	− 1.45 (2.35)	− 1.38 (3.37)	1.28 (1.48)	0.37 (0.92)	0.28	− 0.00	1.17
McHenry NE	− 76.75	0.74 (0.99)	1.81 (1.27)*	− 0.29 (1.59)	—	2.82 (1.74)*	− 1.53 (2.43)	3.01 (1.76)*	− 0.20 (0.60)	0.29	0.06	0.66
McDonough W	455.63	0.36 (1.54)	− 1.59 (1.84)	− 2.02 (2.28)	− 1.73 (2.40)	− 1.03 (2.66)	0.88 (3.06)	− 1.64 (2.63)	0.55 (0.87)	0.26	− 0.02	0.69
McLean C	754.75	− 0.56 (1.50)	− 1.00 (1.78)	− 6.79 (2.59)***	− 0.33 (2.47)	− 2.16 (2.32)	− 3.82 (3.29)	0.42 (2.98)	0.42 (0.85)	0.34	0.09	0.91
Vermillion E	574.15	− 1.12 (1.37)	− 0.88 (1.72)	− 4.27 (2.36)*	− 0.51 (2.38)	− 2.71 (2.40)	0.34 (2.24)	5.21 (2.25)**	—	0.35	0.14	0.97
Sangamon WSW	249.78	1.98 (1.46)*	− 0.96 (2.00)	− 0.88 (2.85)	− 2.54 (2.55)	− 3.97 (2.60)*	0.87 (3.43)	—	2.33 (1.40)*	0.29	0.06	0.84
Shelby ESE	318.10	2.23 (1.69)*	− 1.37 (1.92)	− 0.81 (2.58)	− 3.52 (2.77)	− 3.11 (1.96)*	6.37 (3.16)**	1.53 (3.57)	1.08 (1.07)	0.40	0.17	0.74
St. Clair SW	444.80	0.41 (1.09)	− 0.16 (1.27)	− 2.10 (1.40)*	− 3.63 (1.62)**	− 2.05 (1.45)	4.36 (1.61)***	3.96 (2.58)*	0.96 (0.57)*	0.61	0.46	1.16
Wayne SE	512.49	− 1.14 (1.24)	− 0.45 (1.55)	− 2.16 (2.05)	− 2.78 (2.16)	− 0.44 (2.19)	0.85 (1.87)	4.54 (2.22)*	0.36 (0.77)	0.41	0.19	0.94
Jackson SW	638.66	− 1.21 (0.91)*	NS —	− 1.28 (1.72)	− 5.27 (1.71)**	− 1.99 (1.94)	1.41 (1.21)	2.49 (1.46)*	− 0.13 (0.45)	0.57	0.44	1.24

Numbers in parenthesis are standard errors.
*10% level of significance.
**5% level of significance.
***1% level of significance.

Table 2. A Comparison of Coefficients of Variation in Two Studies for Two Different Time Periods.

Area	CV 1	CV 2
Bureau County (Northwest)	8-14	21
McHenry County (Northeast)	15-19	25
McDonough (West)	15-19	42
Vermillion (East)	15-19	32
Sangamon (West Southwest)	20-24	32
Shelby (East Southeast)	29-38	37
St. Clair (Southwest)	29-38	46
Wayne (Southeast)	29-38	45

CV 1: 1931-1963, from Changnon and Neill, 1967.
CV 2: 1951-1980, from present study.

Fig. 1. Yield of Corn in Bushels Over Time for Three Selected Counties in Illinois, 1951-1980

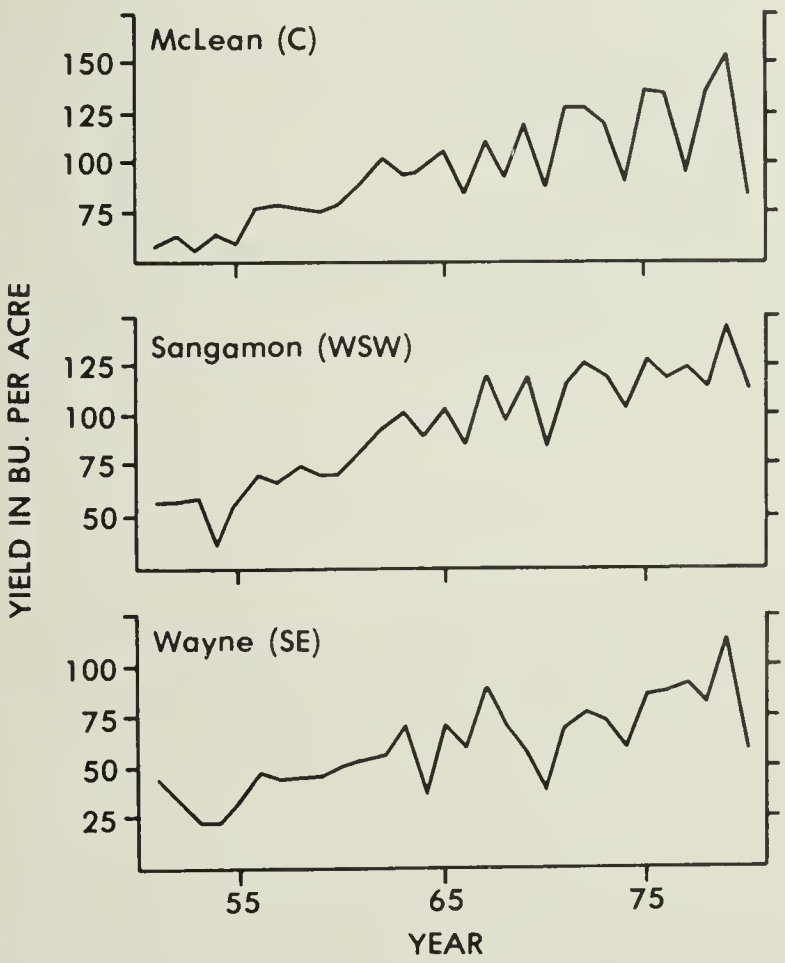
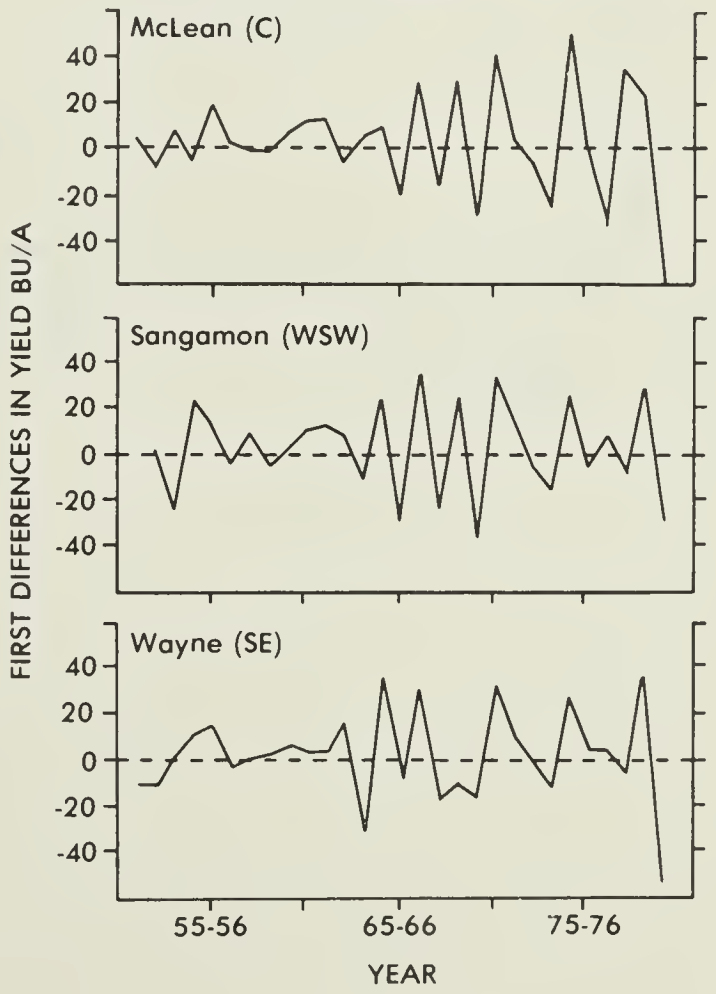


Fig. 2. First-Differences in Corn Yield Over Time for Three Selected Counties in Illinois, 1951-1980



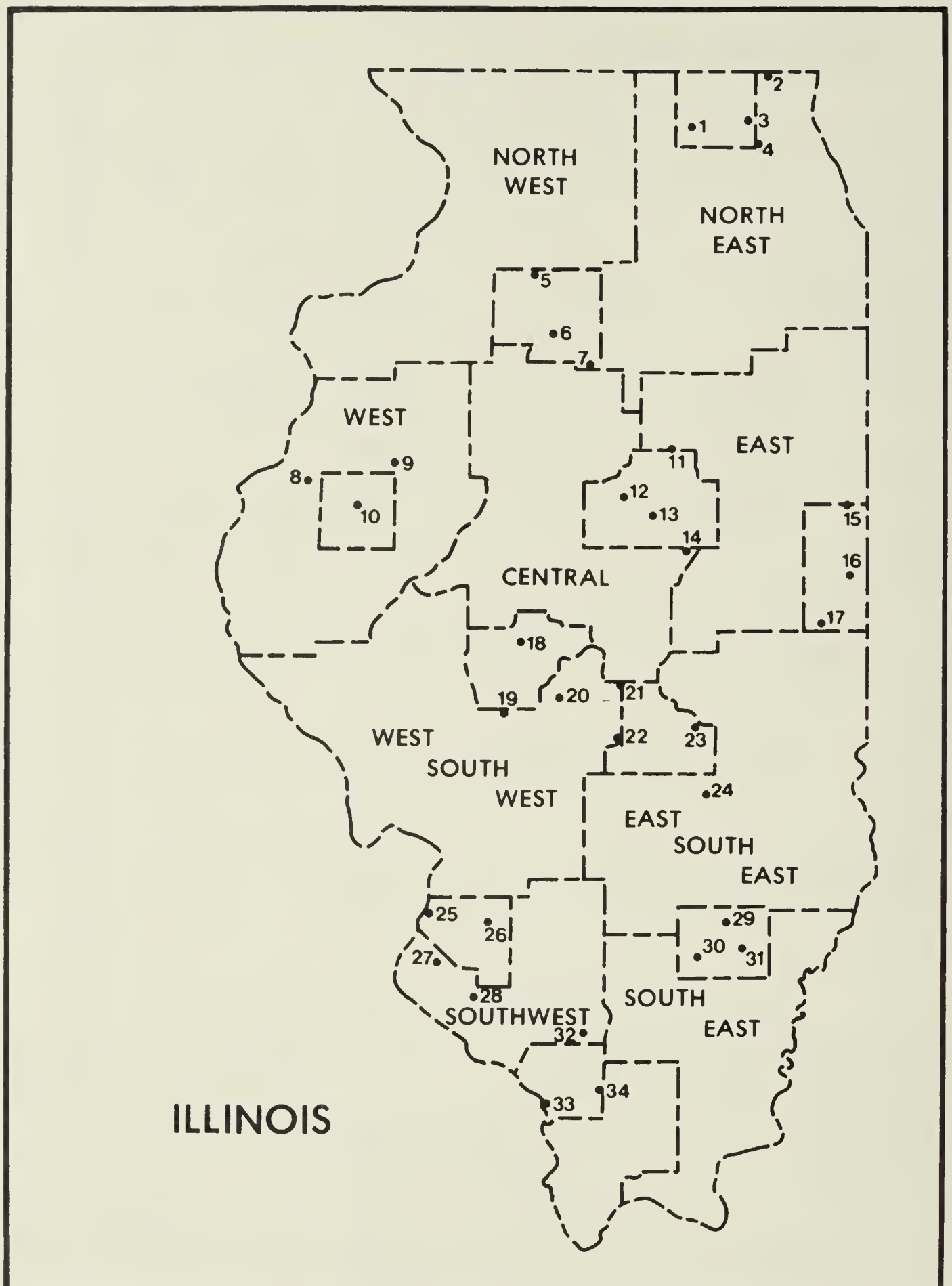


Fig. 3. Location of Study Counties in Illinois and Weather Stations Used For Data on Weather Variables

Key to Figure 3

Map Number	Names of Weather Stations
1	Marengo
2	Antioch 2 NW
3	McHenry Lock & Dam
4	Barrington
5	Walnut
6	Tiskilwa 2 SE
7	Hennepin Power Plant
8	LaHarpe
9	Macomb
10	Avon 5 NE
11	Chenna
12	Bloomington Water Works
13	Downs 2 NE
14	Farmer City
15	Hoopeston 1 SE
16	Danville
17	Sidell
18	Springfield WSO AP
19	Virden 1 N
20	Kinkaid
21	Mowengna
22	Pana
23	Windsor
24	Effingham
25	Cahokia
26	Belleville So. Ill. Univ.
27	Waterloo
28	Sparta
29	Cisne 2 ESE
30	Wayne City 1 N
31	Fairfield Radio WFIW
32	DuQuoin 4 SE
33	Grand Tower 2 N
34	Carbondale Sewage Plant

Table 3. Results of Regressing Corn Yield Against Technology and Weather Variables for Ten Illinois Counties: 1951-1980

	Independent Variables, Estimated Coefficients & Standard Errors										Regression Statistics		
Area & County	Constant	Tec	MT	JT	JLT	AT	JNP	JLP	AP	SNP	R^2	$\bar{R}^2$	DW
Bureau NW	100.81	1.32 (0.17)***	—	0.36 (0.82)	−1.45 (1.08)*	0.39 (0.82)	−1.14 (1.19)	−0.61 (1.69)	0.62 (0.75)	−0.17 (0.47)	0.81	0.74	3.03
McHenry NE	−4.50	1.29 (11.73)***	0.08 (0.22)	1.18 (2.51)**	−1.22 (2.07)*	0.51 (0.91)	0.67 (1.02)	1.58 (1.70)*	1.52 (2.30)**	−0.66 (3.00)***	0.91	0.87	1.97
McDonough W	−24.62	1.59 (0.17)***	0.52 (0.69)	0.55 (0.86)	−1.70 (1.03)*	1.47 (1.14)	−0.39 (1.20)	1.86 (1.38)*	−2.55 (1.19)**	0.09 (0.40)	0.86	0.79	2.02
McClean C	343.40	1.58 (0.19)***	—	0.21 (0.85)	−4.12 (1.27)***	−0.19 (1.06)	−0.82 (1.05)	1.13 (1.69)	−0.97 (1.27)	—	0.84	0.79	2.41
Vermillion E	323.69	1.61 (0.16)***	−0.48 (0.60)	0.45 (0.75)	−3.60 (1.05)***	−0.33 (1.03)	−0.58 (1.06)	1.09 (0.97)	0.97 (1.06)	−0.49 (0.38)	0.89	0.84	2.48
Sangamon WSW	197.59	1.95 (0.17)***	1.04 (0.57)*	—	−1.89 (1.04)*	−1.47 (0.98)*	−0.19 (1.00)	1.57 (1.28)	−0.18 (1.07)	−0.09 (0.56)	0.90	0.86	2.33
Shelby ESE	226.71	1.68 (0.17)***	1.43 (0.17)**	−0.14 (0.81)	−1.99 (1.08)**	−2.13 (1.16)**	−1.14 (0.84)*	3.33 (1.35)**	0.95 (1.48)	0.21 (0.45)	0.90	0.86	2.64
St. Clair SW	202.85	1.09 (0.18)***	0.66 (0.67)	0.53 (0.78)	−2.47 (0.86)***	−1.38 (1.06)	−0.91 (0.91)	3.55 (0.99)***	1.69 (1.62)	0.75 (0.35)**	0.86	0.80	1.64
Wayne SE	273.86	1.11 (0.20)***	−0.34 (0.81)	0.37 (0.81)	−1.80 (1.32)*	−1.88 (1.40)*	−1.59 (1.43)	1.97 (1.22)*	2.44 (1.48)*	−0.09 (0.50)	0.77	0.66	1.76
Jackson SW	419.69	0.86 (0.20)***	−0.60 (0.70)	0.71 (0.94)	−1.81 (1.31)*	−3.55 (1.35)***	−0.94 (1.51)	1.49 (0.93)*	1.02 (1.23)	−0.10 (0.34)	0.78	0.68	1.76

All values in parenthesis are standard errors.
* 10% level of significance.
** 5% level of significance.
*** 1% level of significance.

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EFFECTS OF POPULATION DENSITY AND FISHING PRESSURE ON HOOK-AND-LINE VULNERABILITY OF LARGEMOUTH BASS

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ABSTRACT

A two-part investigation was conducted on the angling vulnerability of northern largemouth bass, *Micropterus salmoides salmoides*, by manipulating population density in experimental ponds and fishing pressure applied to these populations. In the first experiment, three 0.08-hectare ponds were stocked with different densities of largemouth bass (50, 150, and 300 per hectare), and each pond was fished an equal number of hours. Catch per hour values for the low, medium, and high density ponds were 0.11, 0.72, and 1.61, respectively. The data indicated that a direct relationship exists between population density and the catch rate of largemouth bass. In the second experiment, three 0.08-hectare ponds were stocked with equal densities of largemouth bass (175 per hectare) and each pond was subjected to a different level of fishing pressure. The low pressure pond received 70.83 hours per hectare and yielded 2.99 bass per hour. The moderate pressure pond received 141.67 hours per hectare and yielded 1.15 bass per hour. The high pressure pond received 283.33 hours per hectare and yielded 0.35 bass per hour. The data indicated that an inverse relationship exists between fishing pressure and the catch rate of largemouth bass.

INTRODUCTION

Previous studies have demonstrated the effects of population density on growth, production, and catch rate of sport fish (Backiel and Le Cren 1967; Bennett 1954, 1971; Bennett et al. 1969). Bennett et al. (1969) reported that population densities and weights of bluegill, *Lepomis macrochirus*, and largemouth bass, *Micropterus salmoides*, were the most important differences between "good and poor" fishing years in a 7.28 hectare Illinois lake. They observed that for years in which the fish populations were dense, competition for available food resulted in higher catch rates. According to Beukema (1969) initial angling success for carp, *Cyprinus carpio*, increased rapidly with increased stocking densities. Data documented by Beaty and Childers (1980) indicated high correlation ($r = 0.80$) between population density and catch rate in four 0.1-hectare ponds, each containing largemouth bass, smallmouth bass (*Micropterus dolomieui*), and F_1 hybrids (female

largemouth bass × male smallmouth bass). Aldrich (1939) noted, however, that in Spavinaw Lake, Oklahoma, increasing the density of the largemouth bass population did not result in a proportionate increase in catch rate. A study of several Illinois ponds (Hansen et al. 1960) also found little correlation between numbers of bass and bluegills and the catch rate.

The relationship between population density and catch rate is subject to numerous variables (e.g., food availability, social behavior, and hook-avoidance learning). Lagler and De Roth (1953) reported that population density of largemouth bass (TL 254 mm) influenced angling success in the Upper and Lower Loch Alpine ponds in Michigan. Lower Loch Alpine, containing 42 bass per hectare, yielded 0.25 bass per man-hour, whereas Upper Loch Alpine, containing 15 bass per hectare, yielded 0.04 bass per man-hour. However, total hours of fishing pressure placed upon the two ponds were not equal (232 man hours in Lower L.A. and 79 man hours in Upper L.A.). The differential fishing pressure may have greatly affected catch rate. The effect of fishing pressure needs to be assessed independently (Bennett and Weiss 1959; Anderson and Heman 1969). The objectives of this study were to reexamine for populations of largemouth bass under controlled experimental conditions: (1) the relationship between population density and catch rate and (2) the relationship between fishing pressure and catch rate.

METHODS

The study was conducted at the Aquatic Research Field Laboratory of the Illinois Natural History Survey, located on the Urbana-Champaign campus of the University of Illinois. Northern largemouth bass, *Micropterus salmoides salmoides*, collected from a 5.7-hectare lake which had received minimal fishing pressure, were stocked into three 0.08-hectare ponds. Spaghetti-type tags (Floy FD-68B) were attached to each fish below the dorsal fin. Those fish which lost either the numbered sleeve or the entire tag were retagged when caught by fishermen.

POPULATION DENSITY EXPERIMENT

In October 1978, Pond A (low density) was stocked with four largemouth bass (50 bass per hectare); Pond B (medium density) with 12 largemouth bass (150 bass per hectare); and Pond C (high density) with 24 largemouth bass (300 per hectare). All bass were weighed, measured, and tagged prior to stocking; mean total lengths and weights were similar (Table 1). Each of the three ponds was stocked with approximately 0.8 kg of fathead minnows, *Pimephales promelas*, as forage in fall 1978 and in spring 1979.

To allow for acclimation of the fish and to determine handling mortality, the ponds were not fished for 2 weeks after stocking. Thereafter, fishing was conducted in discrete 45 minute test periods. During a 45 minute test period, each of the three ponds was fished for 15 minutes. As a result, each population received the same fishing pressure at approximately the same time. To minimize hook-and-line mortality, fishermen were restricted to artificial lures. During a test period, a given lure was used equivalently in each of the three ponds. All largemouth bass caught were weighed, measured, fin clipped, and returned to their respective

ponds. Fishing was conducted for 1 week in fall 1978 (16-20 October) and 7 weeks in 1979 (11 May - 9 July). Each pond was fished 4.5 hours (56 hours per hectare) in fall and 13.5 hours (169 hours per hectare) in spring, totaling 18 hours (225 hours per hectare) for the experiment. Upon termination of the experiment, the ponds were drained and largemouth bass were weighed and measured. All largemouth bass originally stocked were recovered.

FISHING PRESSURE EXPERIMENT

In September 1979, three 0.08-hectare ponds were stocked with 14 largemouth bass; mean total lengths and weights were similar (Table 2). To provide forage each pond was stocked in fall 1979, with 1.36 kg of sticklebacks, *Eucalia inconstans*.

Ponds were not fished for 2 weeks after stocking to allow for acclimation and determination of handling mortality. Thereafter, fishing was conducted in discrete 70 minute test periods. During a given 70 minute fishing period Pond A was fished for 10 minutes, Pond B for 20 minutes, and Pond C for 40 minutes. Each 70 minute test period was considered one trial by one fisherman. Fishing was conducted 22 April - 20 June 1980 providing 34 fishing trials. The fishing experiment was divided into two sessions. Session I included the first 4 days of the fishing experiment, when 11 trials were conducted to determine the effect of intense fishing pressure over a short time period. Fishing throughout Session II, the remainder of the experiment, averaged one fishing trial every 2 days, totalling 23 trials over a 7 week period. At the end of the experiment, all ponds were drained and largemouth bass were measured and weighed. All 14 largemouth bass were recovered from Pond B; Ponds A and C each had 13 bass at the time of draining.

RESULTS

Population Density Experiment

Catch rates for the combined fall and spring fishing sessions in the low, medium, and high density ponds were 0.11, 0.72, and 1.61 bass per hour, respectively (Table 3). Two of four (50%) bass were caught in the low density pond; nine of 12 (75%) in the medium, and 20 of 24 (83.3%) in the high density pond. The low density pond was the only one in which no recaptures occurred (Fig. 1). Of the nine individual largemouth bass caught in the medium density pond, seven were caught once each, and three twice each, yielding 13 captures. In the high density pond, of 20 individuals caught, 12 were caught once each, seven twice each, and one three times, a total of 29 captures. A positive correlation ($r = 0.99$) existed between the catch rate of largemouth bass and population density in the experimental ponds (Fig. 2). Theoretically, one might expect that as population density increased there would be an accompanying proportional increase in rate of catch. However, comparing low and medium density ponds, as density increased by a factor of three, catch rate increased by a factor of 6.6. Comparison of low and high density ponds revealed a similar effect; as density increased by a factor of six, catch rate increased by a factor of 14.6. This descrepancy was not as pronounced when comparing medium and high density ponds; as density increased by a factor of two, catch rate increased by a factor of 2.2.

Fishing Pressure Experiment

During spring Session I, ponds A and B yielded two largemouth bass, while in Pond C no bass were captured despite high fishing pressure. In Session II, anglers captured 15 largemouth bass in Pond A, 11 in Pond B, and 8 in Pond C. During the same period, catch rates per hour were 3.92, 1.43, and 0.52, respectively (Table 4). Catch rates of the combined two spring fishing sessions (34 trials) also decreased as pressure increased (Table 4). Numbers of largemouth bass caught per hour in ponds A, B, and C were 2.99, 1.15, and 0.35, respectively. There was a significant negative correlation (– 0.913) between catch rate and fishing pressure over the entire spring period.

To determine possible effects of fishing pressure on catch rate within trial periods, numbers of bass caught during 10 minute segments of the trial periods were calculated (Table 5). Low pressure Pond A, which received only 10 minute fishing trials, was compared to the first 10 minutes of fishing in moderate pressure (20 minute trial) Pond B and high pressure (40 minute trial) Pond C. Eighty-five percent of the bass captured in Pond B were captured during the first 10 minutes of each fishing trial. The first 10 minutes of angling in Pond C, however, yielded only 37.5% of the total catch. By the time 200 hours per hectare (24 trials) had accumulated in Pond C, the catch rate dropped to zero, while in Pond B zero catch rate occurred after 121 hours per hectare (29 trials). Pond A continued to yield largemouth bass throughout the experiment (70.83 hours per hectare for 34 trials).

In Pond A, of 11 individual bass captured, five (45.5%) were captured only once, whereas six (54.5%) were captured twice each, totaling 17 captures (Fig. 3). In Pond B, of 11 individual bass captured, nine (82%) were each caught once, whereas two (18%) were caught twice each, totaling 13 captures. In Pond C, of six individual bass captured, four (67%) were each caught only one time and two (33%) were caught twice each, totaling eight captures.

As mentioned, the fish were fin clipped each time they were caught to insure detection of multiple captures when a tag was lost. This was indeed fortuitous, for of the 45 tags (including retagging) used during the population density experiment, 38% lost the numbered identification sleeve. In the fishing pressure experiment, 31% of 58 tags were lost. Fish were often observed striking at tags carried by neighboring individuals.

DISCUSSION

Assuming that higher density populations of largemouth bass have a greater number of actively feeding individuals at a given time, catch rates for dense populations might be expected to be higher than those for sparse populations. Numerical values for "angling efficiency" (number caught per hour per density) of the three ponds were calculated (Table 3). These values indicate success rates on a per fish basis for each catch in a pond with a particular population density. In the low density pond, angling efficiency for catching one largemouth bass during 1 hour of fishing was 0.028; in contrast, medium and high density pond angling efficiencies were 0.060 and 0.067, respectively. Therefore, as the density increased, so did the angling efficiency for capturing any given fish. These results indicate that fewer bodies of water holding more fish at higher density would provide bet-

ter harvest values than if the same fish were spread over more bodies of water at lower density. These increased efficiencies are presumably due to increased aggressiveness among the largemouth bass as a result of increased competition for food resources. Bennett et al (1969) concluded that as fish populations became more dense, competition for available food resulted in higher catch rates. Similar results have been reported by some researchers (Lagler and De Roth 1953; Beukema 1969; Beaty and Childers 1980), while conflicting results are suggested by others (Aldrich 1939; Hansen et al. 1960). Our results agree with those studies showing a positive relationship between increased population density and "high" catch rate.

All three ponds were stocked with equal amounts of forage; however, only the low density pond contained minnows (3.75 kg) at the end of the experiment. The largemouth bass in all ponds spawned during the study, and at the time of draining the number of surviving offspring recovered from the low, medium, and high density ponds were 6,263, 4,549, and 1,393, respectively. Mean lengths of juvenile largemouth bass in the three ponds were 34, 47, and 51 mm, respectively. The negative relationship between number of spawners and resulting year class indicated severe cropping of juveniles by adults in both medium and high density ponds. Adult largemouth bass in the low density pond gained weight, while adults in the other two ponds lost weight. These results indicate that food resources were indeed limiting in the medium and high density ponds (Table 1).

Our data indicate that vulnerability to angling decreased as fishing pressure accumulated (Fig. 3). Data from Anderson and Heman (1969) suggested that largemouth bass vulnerability may have been inversely related to previous fishing pressure. Analyzing lakes and ponds from both Illinois and Missouri, Bennett and Weiss (1959) found at fishing pressures below 325 hours per hectare, catch rate increased rapidly and was greatest when pressures were between 100 and 150 hours per hectare. In our experiment, the highest rate of catch was in Pond A, which received 70.83 hours per hectare, the lowest fishing pressure studied. Furthermore, in moderate and high pressure ponds (B and C), the rate of decline in catch per hour within ponds showed a temporal trend of decreasing vulnerability as fishing pressure accumulated. There was no progressive decline in catch rate in low pressure Pond A.

Both experiments presented were conducted in small inpoundments (0.08-hectare); with only one size class of largemouth bass (230 to 310 mm). Effects of limited food resources in a lake or pond are likely to be compounded by the presence of other size classes of bass and other species of fish. As a result of these limitations, we suggest that further studies be conducted and analyzed carefully before relating results to larger bodies of water. However, based on our data, an individual body of water can be managed for maximum catch rate and efficiency by controlling population density of largemouth bass and fishing pressure. Clearly, density of largemouth bass in a pond can be increased to a point at which food resources become insufficient to support growth. Even with increases in catch rate due to increased population densities, stunted largemouth bass caught from an overpopulated pond might lower the quality of fishing. In any case, a management program for a given largemouth bass population must be designed so that both growth potential and angling are considered.

ACKNOWLEDGMENTS

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Table 1. Length and weight of largemouth bass at time of stocking and draining of three ponds for the population density experiment.

	POND A low density [a]	POND B medium density [b]	POND C high density [c]
Stocking			
Number	4	12	24
Mean Total Length (mm)	272 ± 9	271 ± 24	271 ± 14
Mean Total Weight (g)	329 ± 57	316 ± 88	314 ± 55
Draining			
Number	4	12	24
Mean Total Length (mm)	307 ± 13	285 ± 15	278 ± 12
Mean Total Weight (g)	413 ± 41	301 ± 41	275 ± 37
Percent of Change			
Mean Total Length (mm)	+12.9	+5.2	+ 2.6
Mean Total Weight (g)	+25.5	−4.8	−12.4

Standard deviations are indicated to the right of each value.
[a]Low density: 4 individuals (50 per hectare).
[b]Medium density: 12 individuals (150 per hectare).
[c]High density; 24 individuals (300 per hectare).

Table 2. Length and weight of largemouth bass at time of stocking and draining for the fishing pressure experiment.

	POND A low pressure [a]	POND B moderate pressure [b]	POND C high pressure [c]
Stocking			
Number	14	14	14
Mean Total Length (mm)	266 ± 29	268 ± 29	263 ± 30
Mean Total Weight (g)	283 ± 75	290 ± 89	278 ± 83
Draining			
Number	13	14	13
Mean Total Length (mm)	290 ± 22	278 ± 24	292 ± 32
Mean Total Weight (g)	330 ± 59	272 ± 80	336 ± 103
Percent of Change			
Mean Total Length (mm)	+ 9.0	+3.7	+11.0
Mean Total Weight (g)	+16.6	−6.2	+20.9

Standard deviations are indicated to the right of each value.
[a]Low pressure: 10 minutes per trial.
[b]Moderate pressure: 20 minutes per trial.
[c]High pressure: 40 minutes per trial.

Table 3. Combined rates of the fall and spring sessions for three ponds stocked with different densities of adult largemouth bass. Angling efficiencies are shown as catch rate divided by density.

	POND A low density [a]	POND B medium density [b]	POND C high density [c]
Catch per hour	0.11	0.72	1.61
Catch rate per density	0.028	0.060	0.067
Kilograms per hour	0.03	0.20	0.42

[a]Low density: 4 individuals (50 per hectare).
[b]Medium density: 12 individuals (150 per hectare).
[c]High density: 24 individuals (300 per hectare).

Table 4. Fishing pressure and catch rates for largemouth bass fishing pressure experiment.

	POND A low pressure [a]	POND B moderate pressure [b]	POND C high pressure [c]
Spring 1980 - Session I			
April 22-25 (11 trials)			
Hours fished	1.83 (22.92 per ha)	3.67 (45.83 per ha)	7.33 (91.63 per ha)
Catch per hour	1.09	0.55	0.00
Catch per hectare	25.0	25.2	0.0
Spring 1980 - Session II			
May 1-June 20 (23 trials)			
Hours fished	3.83 (47.88 per ha)	7.67 (95.88 per ha)	15.33 (191.63 per ha)
Catch per hour	3.92	1.43	0.52
Catch per hectare	187.5	137.5	100.0
Total of Sessions I and II			
April 22-June 20 (34 trials)			
Hours fished	5.67 (70.83 per ha)	11.33 (141.67 per ha)	22.67 (283.33 per ha)
Catch per hour	2.99	1.15	0.35
Catch per hectare	211.5	162.5	99.2

[a]Low pressure: 10 minutes per trial.
[b]Moderate pressure: 20 minutes per trial.
[c]High pressure: 40 minutes per trial.

Table 5. Number of largemouth bass caught in three fishing ponds (A, B, and C) during the first, second, third, and fourth 10 minutes across 34 fishing trials for the combined two spring fishing sessions.

Spring 1980	POND A low pressure [a]	POND B moderate pressure [b]	POND C high pressure [c]
1st 10 minutes	17 (100%)	11 (85%)	3 (37.5%)
2nd 10 minutes	--	2 (15%)	2 (25%)
3rd 10 minutes	--	--	0
4th 10 minutes	--	--	3 (37.5%)
TOTAL	17	13	8

[a]Low pressure: 10 minutes per trial.
[b]Moderate Pressure: 20 minutes per trial.
[c]High pressure: 40 minutes per trial.

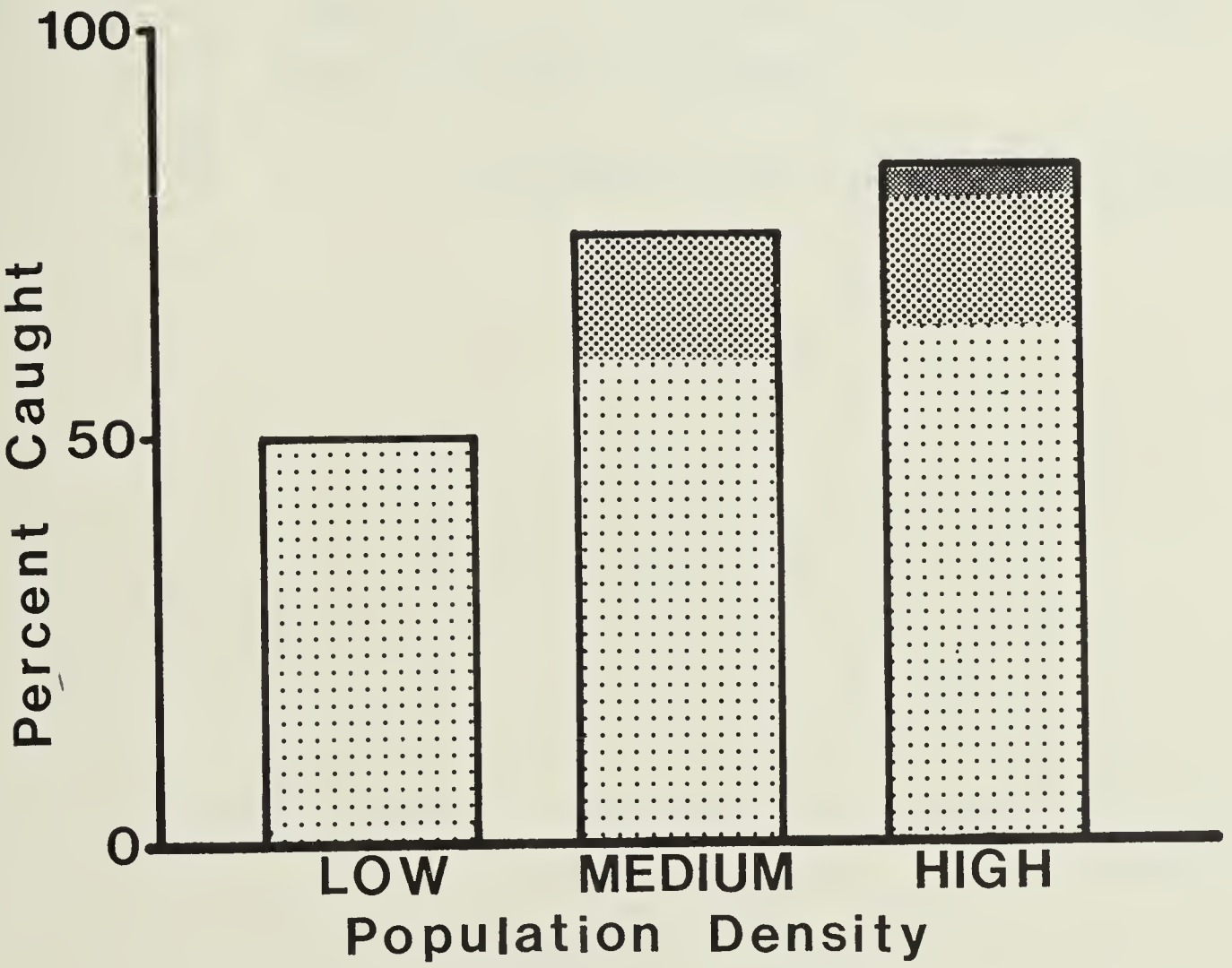

Figure 1. Precentage of largemouth bass population caught in Pond A (low density), Pond B (medium density), and Pond C (high density). Lightly shaded areas indicate percentage of captured bass caught one time; darker shaded, two times; and heavily shaded, three times.

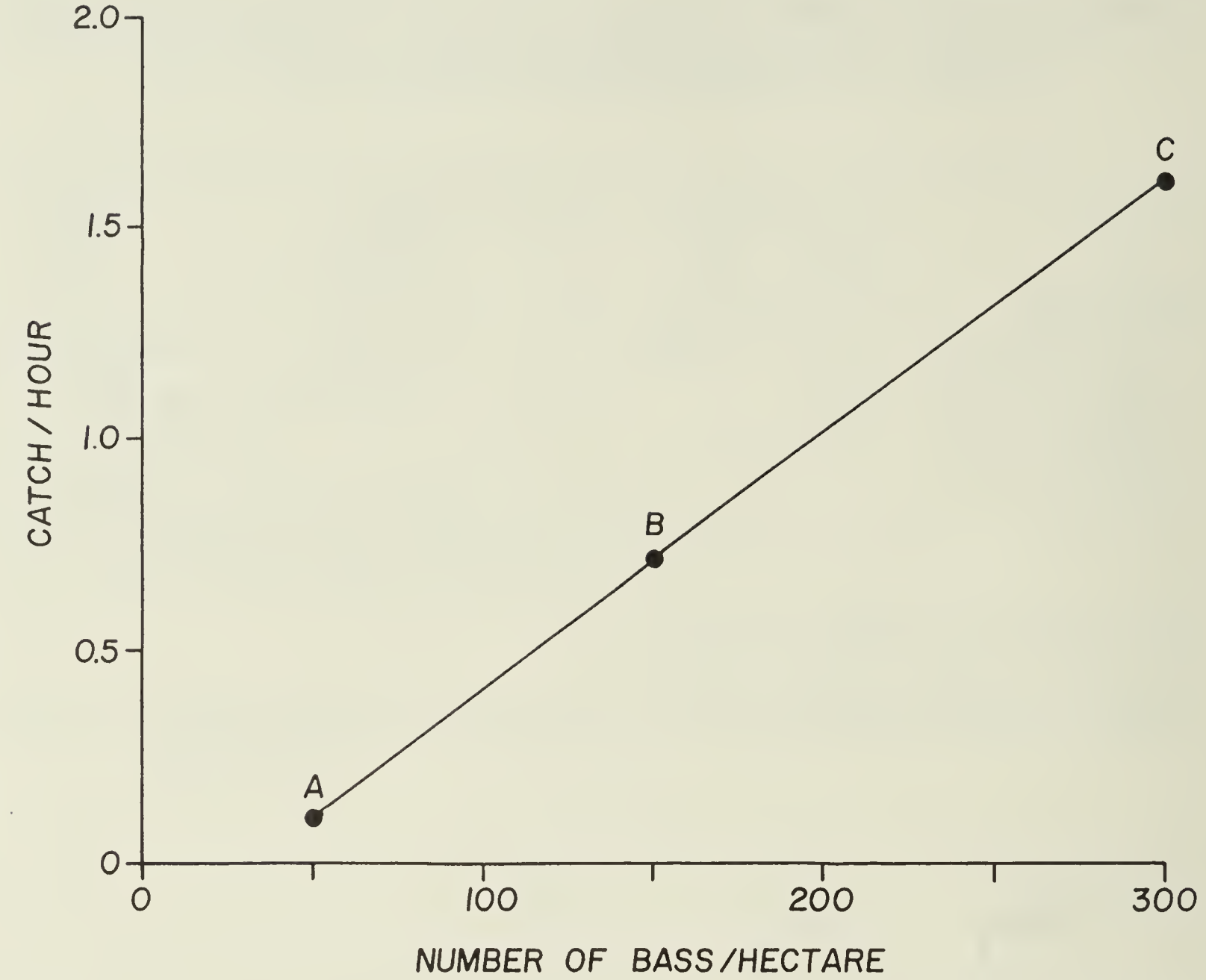

Figure 2. Relationship between catch rate and population density of largemouth bass in Pond A (low density), Pond B (medium density), and Pond C (high density).

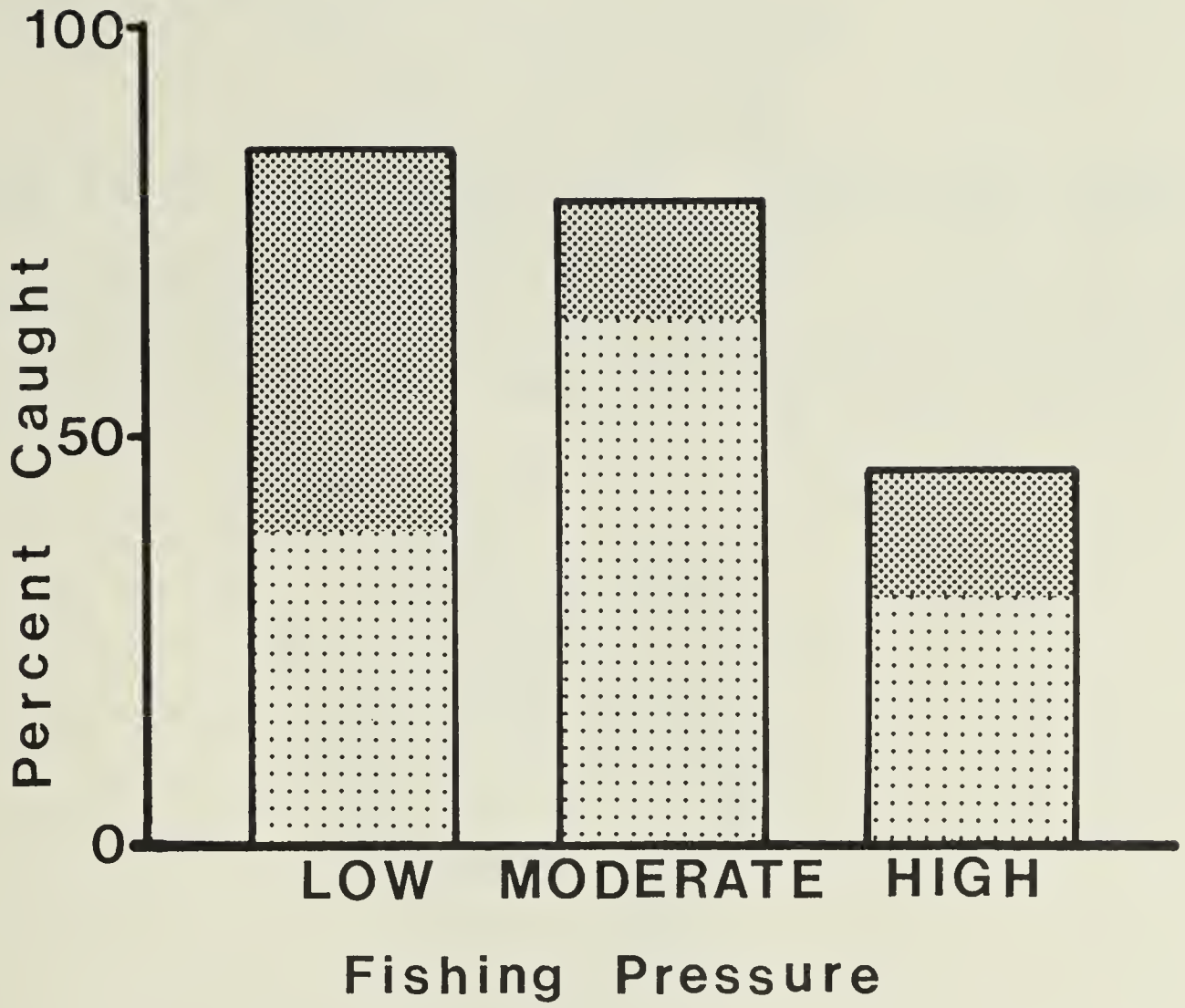

Figure 3. Percentage of largemouth bass population caught in Pond A (low pressure), Pond B (moderate pressure), and Pond C (high pressure). Lightly shaded areas indicate percentage of captured bass caught one time, and darker shaded areas indicate two times.

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EFFECT OF ABSCISIC ACID ON ION TRANSPORT AND TRANSLOCATION IN *HORDEUM VULGARE* SEEDLINGS

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ABSTRACT

The effect of abscisic acid (ABA) on potassium ion transport into roots and ion translocation into shoots of intact *Hordeum vulgare* seedlings was studied. The presence of 10^{-6}, 10^{-5}, or 10^{-4} molar ABA in the absorption solution caused an increase in potassium transport into roots and prohibited translocation of ions to the shoot. These effects were observed at both 0.1 mM and 20 mM absorption solution potassium ion concentrations. The results are discussed in terms of water stress adaptation by the intact seedling.

INTRODUCTION

The phytohormone abscisic acid (ABA) plays many roles in plant growth and development. Water stress adaptation, root geotropism, seed development and germination, dormancy, correlative inhibition of buds, and ion movement are just a few of the many responses that are mediated in one way or another by ABA (Walton, 1980).

One of the most studied aspects of ABA action on ion transport is the regulation of the movement of potassium ions, protons, and chloride ions which cause turgor changes within guard cells. It is known that ABA inhibits potassium ion uptake by guard cells (Horton and Moran, 1972). Since an active potassium ion -proton exchange is thought to be involved in the regulation of guard cell turgor (Raschke, 1977), it is easy to see that ABA could affect turgor changes within guard cells by altering the movement of potassium ions.

In addition to its apparent effect on potassium ion transport in guard cells, ABA can also affect ion transport in other tissues. ABA has been shown to inhibit potassium ion uptake and proton extrusion in germinating seeds of *Raphanus*

sativus (Ballarin-Denti and Cocucci, 1979), and to inhibit potassium and chloride ion uptake by *Avena* coleoptiles (Reed and Bonner, 1974).

The effects of ABA on ion transport in roots are still a matter of dispute in the literature. It has been reported that ABA both promotes (Karmoker and Van Steveninck, 1979) and inhibits (Shaner *et al.*, 1975) the uptake of ions into roots, and both promotes (Collins and Kerrigan, 1974) and inhibits (Cram and Pitman, 1972) the movement of ions across roots and into the xylem exudate. Pitman, *et al.* (1974) have shown that, depending on the conditions under which plants were grown, ABA either promotes or inhibits ion transport and translocation across the root. They found that in roots excised from dark-grown, low-salt plants, the presence of ABA in the absorption solution caused a decrease in the amount of potassium ion in the xylem exudate. If dark-grown, high-salt roots were used, ABA in the absorption solution caused the amount of potassium ion in the root exudate to increase. This increase was not seen in roots excised from light-grown, high-salt plants. Therefore, it is obvious that the conditions under which plants are grown play an important role in determining how the roots of those plants will respond to the application of exogenous ABA.

It is also known that the effects of ABA on ion uptake by excised roots are different from those observed in intact plants of the same species. In excised roots ABA stimulated potassium ion uptake, while in intact seedlings ABA inhibited potassium ion uptake (Karmoker and Van Steveninck, 1979). This discrepancy in the effect of ABA was explained by these authors as an indication that a variety of factors, such as sugar levels in the tissue, endogenous phytohormone levels, and possible interactions between endogenous and exogenous phytohormones, could be involved in the action of ABA upon ion transport and translocation.

Reports concerning the effects of ABA on the exudate volume flow rate from roots are also contradictory. ABA in the absorption solution increased the exudation volume flow rate in decapitated plants (Glinka, 1973). This increase in volume flow was attributed to an increased hydraulic conductivity of root systems caused by ABA (Glinka, 1977). Other reports in the literature indicate that ABA decreases the volume flow rate and the hydraulic conductivity of root systems (Markhart *et al.*, 1979; Fiscus, 1981). This discrepancy in the literature concerning the effects of ABA on exudate volume flow and hydraulic conductivity in roots was explained by Markhart *et al.*, (1979) as being a combination of differences in species, cultural practices, and ABA concentrations used by different researchers.

As indicated above, there is a considerable amount of disagreement in the literature concerning the effect of ABA on ion transport, translocation, and exudate volume flow in intact plants and excised roots. In an attempt to resolve this disagreement, an experiment was designed in which the effect of ABA on potassium ion transport and translocation in intact *Hordeum vulgare* L. (barley) seedlings was studied.

These experiments should help clarify the contradictory literature for several reasons. First, it is known that damaging plant tissue causes a phytohormone-induced wound response (Dieffenbach *et al.*, 1980). Wounded tissue may respond differently to exogenous application of phytohormones than non-wounded tissue. In experiments reported here, only intact seedlings were used. By using only intact seedlings, the possibility of obtaining erroneous results caused by wounding tissue has been eliminated.

Second, the volume and potassium ion concentration of guttation fluid, as

well as the percent ash weight and potassium ion content of root and shoot tissue was determined in this experiment. These determinations considered together allowed the effect of ABA on ion distribution to be quantified in a precise manner.

Third, two different absorption solution potassium ion concentrations (0.1 and 20 mM) and three different ABA concentrations (10^{-6}, 10^{-5}, and 10^{-4}M) were used in these experiments. Most of the authors, as cited above, used only one absorption solution potassium ion concentration and only one concentration of ABA. By using several different concentrations of both potassium ion and ABA, it would be possible to obtain a more accurate representation of ABA effect on ion transport and translocation.

A study of the effect of ABA on ion transport and translocation, therefore, offered the possibility of giving additional insight into how this phytohormone affects ion movement in intact seedlings. Because of this, the present investigation was undertaken.

MATERIALS AND METHODS

Seeds of barley (cv. Jefferson) were imbibed in Nystatin-treated (0.5mg/100ml), aerated, 0.5 mM calcium sulfate solution. After 24 hours, seeds were placed between moist layers of sterile cheese cloth suspended over 700 ml of aerated 0.5 mM calcium sulfate solution in a 1000 ml beaker. Seedlings were allowed to grow in darkness for 6 days at 25 C.

At the end of 6 days, the calcium sulfate solution was replaced with 0.5 mM calcium sulfate solution containing either 0.1 or 20 mM potassium choride. Abscisic acid (sodium salt) was added to a final concentration of 10^{-6}, 10^{-5}, or 10^{-4} M. A control group of seedlings received equal amounts of sodium with no ABA. All treatments were done in triplicate. The seedlings were covered with plastic bags and left in darkness. After a 24 hour period, guttate was collected, measured with a micro-pipette, and stored in the freezer for later potassium ion analysis. The seedlings were then harvested, weighed, and placed in a 70 C drying oven. After 48 hours, the tissue was weighed again, and placed in a muffle furnace for 6 hours at 500 C. Percent ash weight was determined by dividing the ash weight by the dry weight and multiplying by 100. Percent ash weight indicates that total mineral percentage of the tissue. The ashed tissue was used to determine potassium ion content by method of flame emission spectrophotometry.

RESULTS

In this experiment, the effects of different concentrations of ABA on percent ash weight, potassium ion content, guttate volume flow, and guttate potassium ion concentration were determined.

The presence of ABA in the absorption solution caused the percent ash weight of roots of seedlings grown in 0.1 mM potassium chloride to significantly increase, and had no effect on the percent ash weight of roots of seedlings grown in 20 mM potassium chloride when compared to controls. Roots of seedlings grown in both 0.1 mM and 20 mM potassium chloride showed a significantly higher potassium ion content than did the controls (Table 1).

In shoots of seedlings grown in both 0.1 mM and 20 mM potassium chloride, the presence of ABA caused a significant reduction in the percent ash weight, but no significant differences in the potassium ion concentration, when compared to the controls (Table 1).

Table 1

EFFECT OF ABSCISIC ACID ON
ION TRANSPORT AND TRANSLOCATION

Mean percent ash weight and potassium ion content for six-day-old, dark-grown *Hordeum vulgare* seedlings given 0.1 mM or 20 mM potassium chloride with different concentrations of abscisic acid for twenty four hours. Values represent three replicate samples per treatment.

Tissue	Percent Ash Weight %		Potassium Ion Content μMoles/g D.W.	
0.1 mM KCl				
Roots				
Control	4.10 ± 0.58[1]	a[2]	358.3 ± 61.4	a
10^{-6} M ABA	4.97 ± 0.17	b	667.8 ± 118.7	b
10^{-5} M ABA	5.95 ± 0.89	b	625.8 ± 95.3	b
10^{-4} M ABA	9.69 ± 0.70	b	628.6 ± 157.7	b
Shoots				
Control	6.38 ± 0.80	a	464.6 ± 37.1	a
10^{-6} M ABA	3.82 ± 0.03	b	607.3 ± 92.3	a
10^{-5} M ABA	3.82 ± 0.82	b	588.9 ± 22.1	a
10^{-4} M ABA	3.89 ± 0.91	b	574.1 ± 239.6	a
20 mM KCl				
Roots				
Control	12.04 ± 2.94	a	1130.6 ± 62.1	a
10^{-6} M ABA	10.33 ± 1.67	a	1621.2 ± 243.8	b
10^{-5} M ABA	12.96 ± 0.81	a	1657.1 ± 152.8	b
10^{-4} M ABA	9.71 ± 1.55	a	1378.9 ± 156.3	ab
Shoots				
Control	9.56 ± 1.51	a	764.1 ± 92.9	a
10^{-6} M ABA	6.29 ± 1.30	b	762.1 ± 174.5	a
10^{-5} M ABA	5.67 ± 0.67	b	634.8 ± 70.3	a
10^{-4} M ABA	4.66 ± 0.41	b	577.4 ± 56.8	a

[1]Values represent means ± standard deviation.
[2]Values followed by the same letter are not significantly different (Duncan's Multiple Range, P = 0.05).

Table 2.

EFFECT OF ABSCISIC ACID ON GUTTATE VOLUME FLOW AND POTASSIUM ION CONCENTRATION

Mean guttate volume flow and guttate potassium ion concentration for six-day-old, dark-grown seedlings of *Hordeum vulgare* given 0.1 mM or 20 mM potassium chloride with different concentrations of abscisic acid for twenty four hours. Refer to footnotes for sample sizes.

Treatment	Guttate Volume Flow µliters/hour		Potassium Ion Concentration µMoles/ml
0.1 mM KCl			
Control	2.3 ± 0.6[1]	a[2]	0.04[3]
10^{-6} M ABA	1.1 ± 0.2	b	0.02
10^{-5} M ABA	1.1 ± 0.3	bc	0.02
10^{-4} M ABA	0.8 ± 0.2	c	0.02
20 mM KCl			
Control	1.7 ± 0.4	a	0.16
10^{-6} M ABA	0.8 ± 0.2	b	0.08
10^{-5} M ABA	0.7 ± 0.2	b	0.04
10^{-4} M ABA	0.4 ± 0.1	c	0.04

[1]Values represent mean ± standard deviation (n = 15).
[2]Values followed by the same letter are not significantly different (Duncan's Multiple Range, P = 0.05).
[3]Represents value for one sample.

The guttate volume flow of seedlings grown in 0.1 mM and 20 mM potassium chloride was significantly smaller than the controls, and the potassium ion concentration of the guttate was lower in the ABA treated seedlings than in controls (Table 2).

DISCUSSION

The fact that roots of ABA-treated, intact, dark-grown, low-salt, barley seedlings showed an increase in the potassium ion content suggests that ABA promotes potassium ion transport into the roots. The fact that shoots of ABA-treated seedlings showed a decrease in percentage ash weight and a decrease in the potassium ion concentration of the guttate suggests that ABA inhibits ion translocation across the root and up to the shoot.

These results are in general agreement with other reports in the literature concerning ABA effects on ion transport and translocation in excised roots of barley (Pitman and Wellfare, 1978), and for short-term (3 hour) experiments using intact, light-grown barley seedlings (Dieffenbach *et al.*, 1980). It has been shown that ABA inhibits translocation of ions across the root to the xylem without inhibiting the uptake of ions from the absorption solution by the root (Cram and Pitman, 1972). The data reported here support this view for two reasons. First, the presence of ABA increased the potassium ion content found in the root tissue. If ABA had inhibited ion uptake by roots, it would be expected that the potassium ion content of the roots treated with ABA would be less than the controls. Second, the presence of ABA decreased the potassium ion concentration in the guttate. If ABA had enhanced or had had no effect on potassium ion translocation across the root to the xylem, it would be expected that the potassium ion concentration of the guttate would have been greater or equal to the controls.

The results also indicate that treatment with ABA decreased the volume flow of the guttate. This observed decrease in the guttate volume flow was most likely the result of the ABA-induced decrease in the potassium ion concentration of the xylem sap. This concentration decrease would cause a decrease in the passive movement of water into the xylem of the root, with a corresponding decrease in root pressure, and a subsequent decrease in guttate volume flow.

In shoots, the significant decrease in percent ash weight over that of controls indicates that the total amount of inorganic minerals present in the shoot tissue is reduced by ABA treatment. Subsequent analysis indicated no significant differences in the amount of potassium ion concentration of shoot tissue from ABA treated or control seedlings. One possible explanation for this observation is as follows. It has been reported that, in addition to inhibiting the movement of potassium ions, ABA also inhibits the movement of calcium ions (Pitman and Wellfare, 1978) and chloride ions (Cram and Pitman, 1972) across the root and up to the shoot. Since the absorption solution used contained these ions, it is quite possible that their absence in the shoots of the ABA treated seedlings caused the percent ash weight to be less than that of the shoots of the control seedlings.

SUMMARY

The observed effects of ABA on ion transport and translocation in intact seedlings of barley are as follows:

1) ABA in the absorption solution promotes the transport of potassium ions from the absorption solution into the root.

2) ABA in the absorption solution reduces ion translocation across the root and into the shoot.

It has long been known that ABA accumulates in plants in response to water stress (Wright, 1969). Since exogenous ABA alters the partitioning of ions between

the root and shoot, it is quite possible that this altered partitioning plays a role in the development of water stress resistance.

It is quite possible, therefore, that in water stressed seedlings, increased levels of ABA would lead to higher concentrations of ions in roots, causing a reduction in the osmotic potential of the root tissue. Water would move into the root in response to this reduced osmotic potential and water stress would be alleviated.

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AGE AND GROWTH OF LARGEMOUTH BASS IN LAKE SHELBYVILLE, ILLINOIS

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ABSTRACT

Age and growth of largemouth bass, *Micropterus salmolides*, in Lake Shelbyville, Illinois, were determined based on electrofishing collections made in September of 1979-81. Age-structure analysis indicated that recruitment of largemouth bass was variable; stronger year classes were associated with years that had mean water levels higher than the previous summer. Weighted mean lengths at annulus formation for age I-IV largemouth bass were 133, 247, 311, and 356 mm, respectively. Corresponding calculated weights were 27, 198, 413, and 635 g. The scarcity of largemouth bass older than age IV indicated high mortality after harvestable size ($\geq$356 mm TL) was attained. Analysis of length-frequency distributions indicated a desirable size structure during this study. A decrease in proportional stock density (PSD) from 1979 to 1981, reflected variable recruitment. The percentage of harvestable-size bass ($\geq$356 mm TL) increased from 1979 to 1981, reflecting variable recruitment and reduced mortality caused by imposition of a 356-mm length limit in 1978. Management strategies should be directed toward increasing recruitment of largemouth bass to age I rather than attempting to increase growth rates or improve the condition of older fish.

INTRODUCTION

The largemouth bass, *Micropterus salmoides*, is one of the most important game fish in Illinois. Comparative estimates of age and growth of this species are needed to develop effective management strategies. Although data are available on growth of largemouth bass in smaller bodies of water in Illinois (Carlander 1977), there is little information on growth rates in larger reservoirs.

From scale samples collected in 1975 and 1976, Joy and Tranquilli (1979) reported the growth of this bass in Lake Shelbyville, Illinois, during the first 5 years of impoundment (1971-1975). The purpose of this paper is to describe age and growth of largemouth bass in Lake Shelbyville during the second 5 years of impoundment (1976-1980).

STUDY AREA

Lake Shelbyville, a flood control reservoir in central Illinois, was established in 1970; its major tributaries are the Kaskaskia and West Okaw Rivers. At normal summer pool (182.8 m msl) the reservoir has a surface area of 4,490 ha with mean and maximum depths of 4.9 and 18.0 m, respectively. A draw down of 1.2 m occurs in October. Refill begins the following May. For chemical characteristics see Davis and Storck (1983).

Largemouth bass were sampled at two stations in the reservoir: I in the lower main body and II in the Kaskaskia arm (Figure 1). In January 1978, a 356-mm (14-in) length limit was established for largemouth bass. The principal forage of age I and older largemouth bass is gizzard shad, *Dorsoma cepedianum* (Storck et al. 1982).

METHODS

Largemouth bass were collected in mid-September of 1979, 1980, and 1981 using 230-v, AC boat-mounted electrofishing gear. Collections were made at the two stations on consecutive days; sampling techniques consisted of continuous electrofishing along the shoreline, emphasizing the same area each year. All largemouth bass taken were measured to the nearest millimeter total length (TL) and weighed to the nearest gram.

Scale samples, from all fish collected, were removed below the lateral line at the tip of the pectoral fin, cleaned, impressed on cellulose acetate strips, and examined on a microprojector (26.5X). Age was determined by counting annuli on non-regenerated scales. Total scale radius (distance from the focus to the margin measured along the anteriomedian radius) and distance to each annulus were measured to calculate growth history.

The body length-scale radius relationship was determined from pooled data for all 3 years ($n = 847$) by plotting the mean total length against scale radius for fish in 10-mm length groups. The resulting plot revealed a curvilinear relationship and a line was fitted by eye (Figure 2). Means of total length, scale radius, and distance to each annulus were calculated for each age group in each year and adjusted to fit the line (Bagenal and Tesch 1978). Using the adjusted values, corresponding mean lengths at annulus formation for each age group were determined from the graph. Weighted mean lengths at annulus formation were also established for each age group and for all age groups combined.

The length-weight relationship was determined from 532 largemouth bass age I and older. Age 0 fish were not included because the field scale did not accurately weigh small fish. Log-log plots of mean length against mean weight for fish in 10-mm length groups revealed a linear relationship ($r^2 = 0.995$) that was best described by the equation

$$\log WT = 3.1925(\log TL) - 5.4327 \qquad (1)$$

To evaluate condition, relative weights (Wr, Wege and Anderson 1978) were calculated for individual fish using the equation

$$Wr = W/Ws \times 100 \qquad (2)$$

where W = the actual weight of the fish and Ws = a standard weight determined for fish of the same length. Standard weights were determined using the equation

$$\log Ws = -5.316 + 3.191 \log TL \qquad (3)$$

(Wege and Anderson 1978). Mean Wr values were calculated for each age group and for all age groups combined.

To assess the balance of the largemouth bass population in Lake Shelbyville, proportional stock density values (PSD, Anderson 1976) were determined for each year. PSD (%) was determined by dividing the number of quality-size largemouth bass ($\geq$300 mm TL) by the number of stock-size bass ($\geq$200 mm TL).

Relative stock densities (RSD, Wege and Anderson 1978) of bass $\geq$356 mm TL were determined to evaluate the percentage of harvestable-size bass in the stock. RSD (%) was determined by dividing the number of fish $\geq$356 mm TL by the number of fish $\geq$200 mm TL.

Mean reservoir elevation (meters above mean sea level) from April through October, the normal growing season of largemouth bass in Lake Shelbyville (Joy and Tranquilli 1979), was obtained for each year from data compiled by the U.S. Army Corps of Engineers.

RESULTS AND DISCUSSION

Age Structure

The age structure of largemouth bass collected indicated that recruitment in Lake Shelbyville was highly variable (Figure 3). During 1979 and 1980, the 1977 year class was dominant, comprising 64 and 40% of age I and older fish captured. In 1981 no year class was clearly dominant, excluding young-of-the-year; however, the 1980 year class was most abundant. The strength of the 1978 year class was apparently underestimated in 1979 because greater numbers were collected in 1980 and 1981 (Figure 3).

Growth

Weighted mean lenghts at annulus formation for ages I-IV largemouth bass were 133, 247, 311, and 356 mm, respectively (Table 1). Corresponding calculated weights at annulus formation were 27, 198, 413, and 635 g, respectively. Growth beyond age IV was not determined, because few older fish were collected and their scales were difficult to interpret.

The pooled length-frequency distribution of all bass collected was compared with weighted mean lengths at annulus formation determined by back-calculation (Figure 4). Successive modes in the length-frequency distribution corresponded to weighted mean lengths at annulus formation for age I-IV largemouth bass. Considerable overlap occurred, however, in the length distributions of age II and older fish. The back-calculated mean length of bass at the first annulus was considerably larger than the mean length of young-of-the-year collected in the fall (Figure 4). Back-calculated lengths at the first annulus for the 1979 and 1980 year classes were 116 and 126 mm, respectively; but, mean lenghts of those year classes in September of their first year were 99 and 110 mm. Because little growth occurs between late September and the time of annulus formation, mortality was greater for smaller members of the two year classes between fall of their first and second years of life. Joy (1976) reported an increase in mean total length of young-of-the-year largemouth bass in Lake Shelbyville from 100 mm in December 1975 to 118 mm in March 1976, attributing the increase to greater winter mortality of smaller individuals due to predation and exhaustion of stored energy reserves. Higher winter mortality of smaller members of a year class of largemouth bass has also been reported for Bull Shoals reservoir (Aggus and Elliott 1975) and for Dryden Lake, New York (Green 1982).

The 1977 and 1978 year classes of largemouth bass exhibited the greatest first-year growth in this study, while the 1979 year class exhibited the slowest growth (Table 1). The 1977 and 1978 year classes were considerably stronger than the 1979 year class (Figure 3). Several authors have linked the development of strong year classes and rapid first-year growth of largemouth bass to maintenance of high water levels during most of the growing season (Patriarche and Campbell 1957, von Geldern 1971, Aggus and Elliott 1975, Keith 1975). High levels usually result in an abundance of flooded terrestrial vegetation that increases the food supply and offers protection to young largemouth bass from predation (Aggus and Elliott 1975). In 1977, the mean summer water level was not abnormally high (Table 1) but had increased over 2 m relative to the mean of the previous summer. In 1978, the mean water level again increased nearly 1 m over that in 1977. In both years, large areas of terrestrial vegetation were inundated. In 1979, however, the mean water level differed little from that in 1978, and consequently , little terrestrial vegetation was flooded. Thus, survival and growth of young-of-the-year largemouth bass in Lake Shelbyville were greater in the 2 years in which large areas of terrestrial vegetation were inundated. If winter survival was dependent upon length attained during the first growing season, the rapid growth of fish in the 1977 and 1978 year classes may have enhanced recruitment to age I.

Few largemouth bass older than age IV were collected (Figure 3), indicating high mortality of older age groups. Because largemouth bass generally reach legal size (>356 mm TL) at age IV (Table 1), fishing harvest is the likely cause of this mortality. This hypothesis is supported by lower back-calculated estimates of length for the 1977 and 1978 year classes between years (Lee's phenomenom, Ricker 1975), resulting from the selective removal of faster growing individuals as they attained a harvestable size (Ricker 1975). Further research using population estimates and creel survey data are needed to determine what fraction of this mortality can be attributed to fishing and what fraction to natural causes.

Typically, growth and production of largemouth bass populations in new impoundments are high initially by decline in subsequent years (Bennett 1962). The initial peak in production, usually lasting only 2 or 3 years, results from an abundant food supply and lack of competition. As the reservoir ages, however, inter- and intraspecific competition becomes more severe. In Lake Shelbyville, length attained at annulus I was greater during the first 5 years of impoundment (Joy and Tranquilli 1979, Table 2); but, growth to each subsequent annulus was slightly greater during the second 5 years. Thus, a decrease in the growth of age I and older largemouth bass was not associated with the increasing age of Lake Shelbyville during the initial 10 years of impoundment. In contrast, other authors have reported that after an initial peak, growth of older largemouth bass declined over an extended interval (Patriarche and Campbell 1957, McCrain and Mullan 1960, Bryant and Houser 1971, Chance et al. 1975).

Growth of largemouth bass in Lake Shelbyville was generally greater than reported for other Illinois waters (Table 2). Growth to annulus I was less than the Illinois average (Lopinot 1972) but greater to each subsequent annulus. Growth of largemouth bass in Lake Sangchris and Coffeen Lake, two large impoundments in central Illinois, was substatially greater than that in Lake Shelbyville (Table 2); however, these lakes are cooling reservoirs and have an extended growing season (Joy and Tranquilli 1979, Perry and Tranquill 1983).

CONDITION

The slope of the length-weight regression of largemouth bass was significantly greater than 3.0 (t test, $P < 0.05$), indicating allometric growth. Therefore, traditional measures of condition could not be used to compare fish of different lengths (Ricker 1975). Relative weights (Wr) were calculated instead because they compensate for the inherent change in body form with increasing length and, thus, can be used to compare condition of fish of different lengths (Wege and Anderson 1978, Table 3).

A Wr value of 100 indicates that 75% of the populations of largemouth bass summarized from Carlander (1977) had a lower mean weight for that particular length. A Wr value of 93 indicates that only 50% of the populations had a lower mean weight for that particular length. Average Wr values for largemouth bass at the end of their second through fifth year of growth were 98.1, 93.6, 94.5, and 97.0, respectively (Table 3). Mean Wr values for the population of age II through IV largemouth bass increased from 94.7 to 95.9 from 1979 to 1981 (Table 3). These results indicate that largemouth bass in Lake Shelbyville during this study were in relatively good condition as compared to other populations from which standard weights have been derived.

Changes in Size Structure (1979-81)

Proportional stock density (PSD), an index used to assess the size structure of a species, is based upon the length-frequency distribution of the stock (Anderson 1976). Reynolds and Babb (1978) proposed target PSD values of 40-60% for largemouth bass in small midwestern impoundments dominated by the bass-bluegill combination. Anderson and Weithman (1978) recommended a PSD from 50 to 70% for largemouth bass in Missouri impoundments where gizzard shad is the dominant prey species. PSD values in Lake Shelbyville decreased from 68% in 1979 to 64% in 1980 and to 59% in 1981, indicating that a desirable size structure of largemouth bass was present during all 3 years.

PSD in Lake Shelbyville fluctuated in response to variable recruitment. In 1979, the 1977 year class was dominant (Figure 2). A majority of fish in this year class were $\geq$300 mm TL, resulting in the high PSD value for 1979 (68%). It is likely, however, that PSD was overestimated because the strength of the 1978 year class was underestimated. In 1980, the dominance of the 1977 and 1978 year classes, in conjunction with the relatively weak 1979 year class, resulted in a high PSD value (64%). A decrease in PSD in 1981 (59%) resulted from the recruitment of the 1978 year class into the sport fishery and their subsequent decline in abundance; also, the 1980 year class, which had reached stock size ($\geq$200 mm TL), was the most abundant age group in the sample.

Relative stock density (RSD) is the percentage of any defined size group in the stock (Wege and Anderson 1978). RSD values for largemouth bass $\geq$ 356 mm TL increased from 16% in 1979 to 27% in 1980 to 39% in 1981. This increase in percentage of harvestable largemouth bass reflected the entry of the strong 1977 and 1978 year classes into the sport fishery and a reduction in fishing mortality due to the 356-mm (14-in) length limit imposed in 1978.

Management Implications

The largemouth bass population in Lake Shelbyville is characterized by highly variable recruitment, satisfactory growth and condition, and a high mor-

tality rate of older age groups after they attain a harvestable size (>356 mm TL). Management strategies to enhance the largemouth bass fishery, therefore, should try to increase recruitment rather than growth rates.

The results of this study indicate that growth and survival of young-of-the-year largemouth bass were greatest in years when large areas of terrestrial vegetation were inundated. Consequently, the size of the largemouth bass population may be managed by manipulating water levels. However, the lake is a flood control reservoir, and therefore, this strategy cannot be consistently applied. Alternative strategies to enhance recruitment may involve supplemental stocking of fingerling largemouth bass during years of inadequate reproductive success, or seeding of the reservoir fluctuation zone (Strange et al. 1982) to provide additional food and cover for young-of-the-year. Because our data suggest that winter mortality of young-of-the-year largemouth bass may be size-selective for smaller individuals, recruitment may be enhanced by methods that increase growth of smaller individuals. The effect of differential mortality on subsequent year class strength, however, requires further investigation.

PSD values obtained during this study indicated a desirable size structure of largemouth bass in Lake Shelbyville. It is believed that this is due, in part, to the imposition of the 356-mm length limit in 1978. Changes in the current size limit would affect angler catch and harvest rates of largemouth bass; but, further research in to the causes of high mortality of the older age groups is needed before further changes are proposed.

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Table 1. Calculated lengths (mm) and average growth increments of largemouth bass from Lake Shelbyville. Sample sizes of each age group are in parentheses. Water level is an average from April through October (mmsl).

Year Class	Water Level	Age Group I	II	III	IV
1981	602.8				
1980	599.0	126 (52)			
1979	602.4	116 (57)	228 (23)		
1978	602.3	138 (134)	247 (106)	309 (28)	
1977	599.5	141 (228)	254 (228)	313 (120)	351 (29)
1976	592.1	116 (48)	225 (48)	308 (48)	363 (16)
Weighted mean		133	247	311	356
Annual increment		133	114	64	45
Average weight at annulus formation (g)	27	198	413	635	

Table 2. Calculated total length (mm) at each annulus of large bass from various Illinois waters.

Body of water	Age Group I	II	III	IV	V	n	Source
L. Shelbyville	133	247	311	356	-	527	Present study
L. Shelbyville	153	244	306	330	361	1288	Joy & Tranquilli 1979
Illinois average	160	229	295	343	401	-	Lopinot 1972
L. Sangchris	121	275	358	411	444	69	Joy & Tranquilli 1979
Coffeen L.	168	329	400	434	454	439	Perry & Tranquilli 1983
Ridge L.	206	262	320	348	363	4373	Bennett 1954
Crab Orchard L.	114	241	330	394	439	637	Schneidermeyer et al. 1956
Sportsman's L.	97	206	290	338	378	144	Thompson & Bennett 1949
Johnson Sauk Trail L.	102	183	277	330	386	1750	Rock 1966
Ramsey L.	109	224	287	348	386	1399	Stinauer 1966
Red Hills L.	119	196	267	302	335	1771	Price 1966
L. Chautauqua	163	249	312	363	404	505	Starrett & Fritz 1965

Table 3. Relative weights (Wr) of largemouth bass collected from Lake Shelbyville, September 1979-81. Sample sizes are in parentheses.

Age	Year Collected			Mean for all 3 years
	1979	1980	1981	
I +	93.3 (23)	99.1 (30)	99.6 (52)	98.1 (105)
II +	95.1 (112)	91.9 (75)	91.5 (23)	93.6 (210)
III +	94.5 (35)	95.7 (89)	91.0 (29)	94.5 (153)
IV +	94.2 (6)	97.1 (12)	97.6 (29)	97.0 (47)
Total	94.7 (176)	94.9 (206)	95.9 (133)	

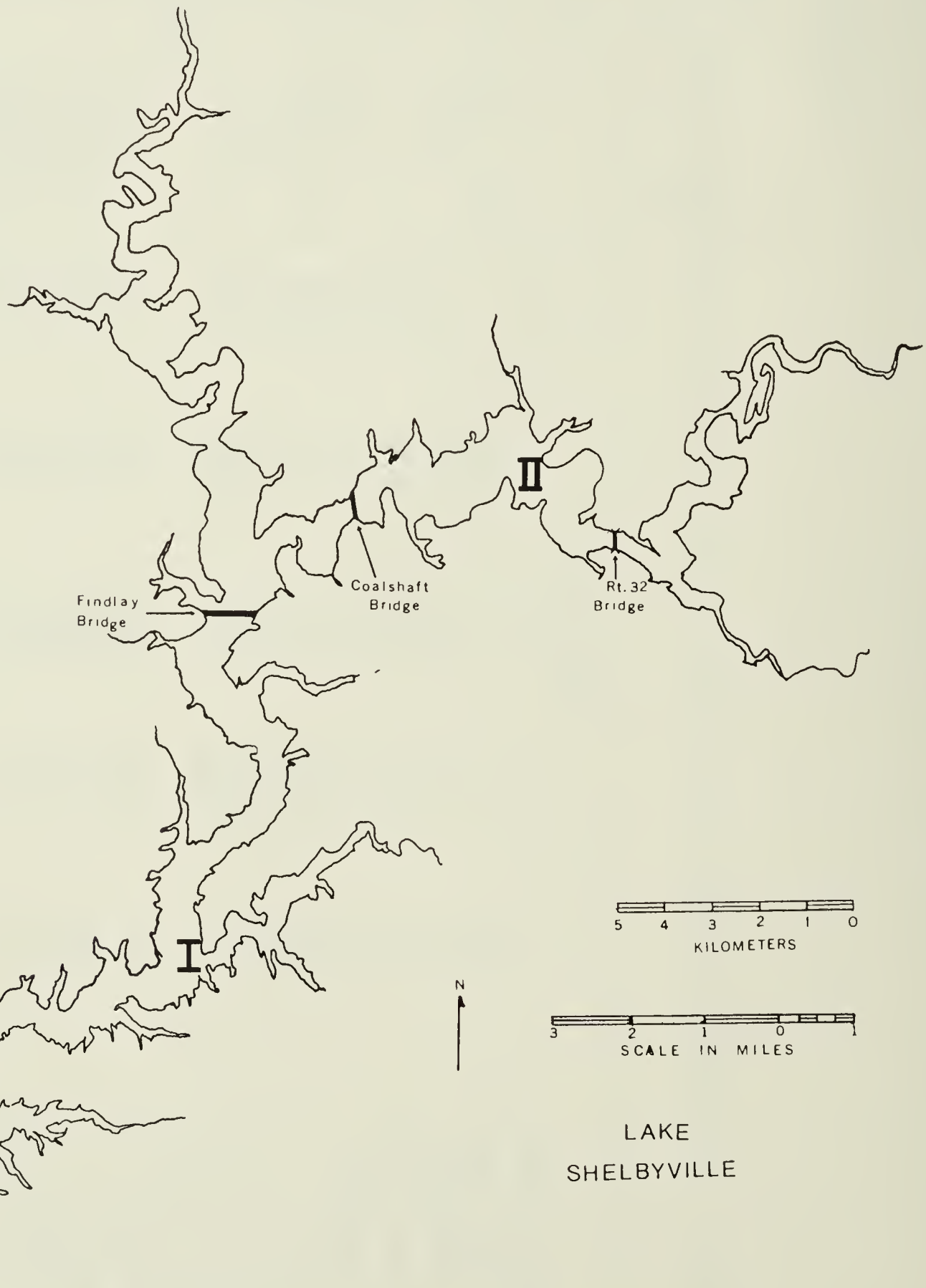

Figure 1. Lake Shelbyville, Illinois, showing stations sampled for largemouth bass.

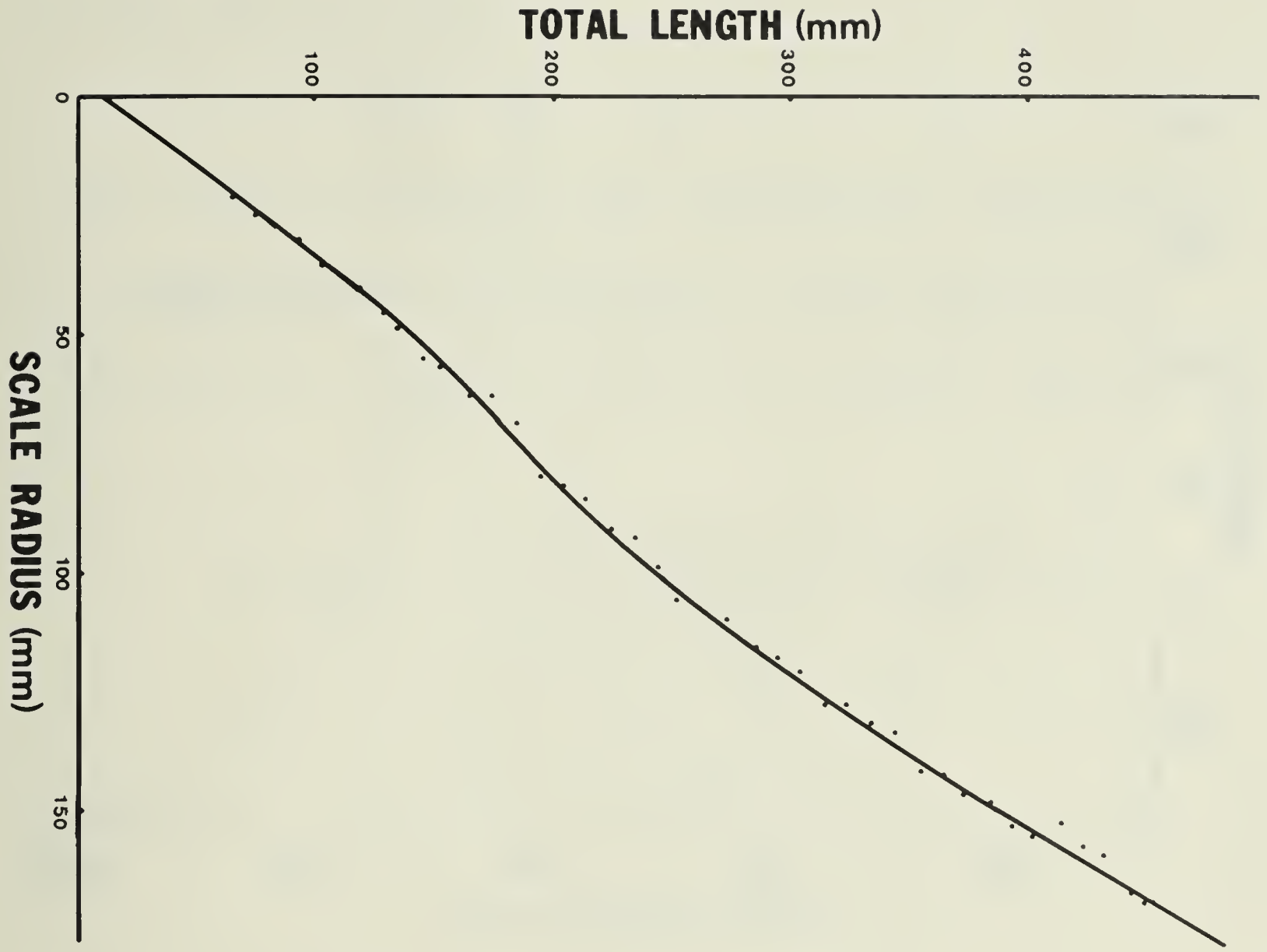

Figure 2. Relation between scale radius (x26.5) and total fish length for largemouth bass collected from Lake Shelbyville, September 1979-1981.

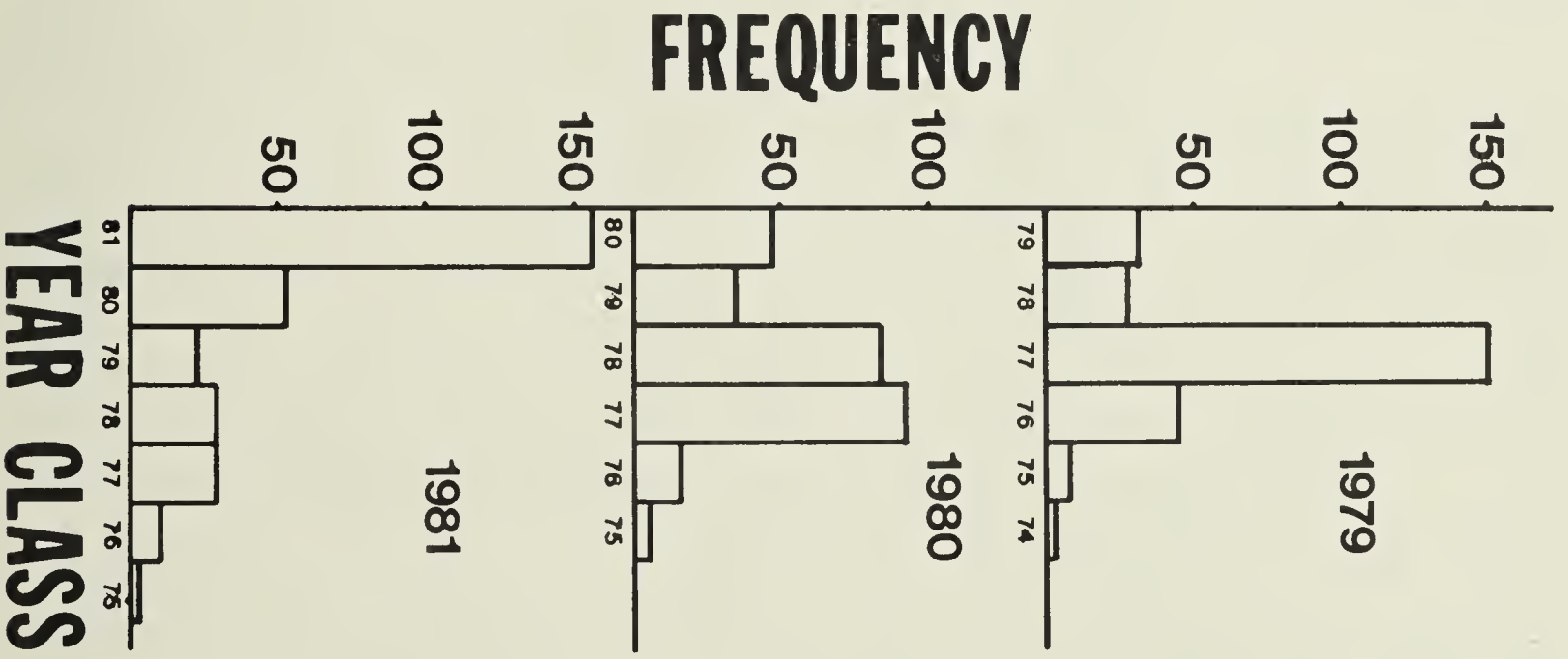

Figure 3. Age structure of largemouth bass collected from Lake Shelbyville, September 1979-1981.

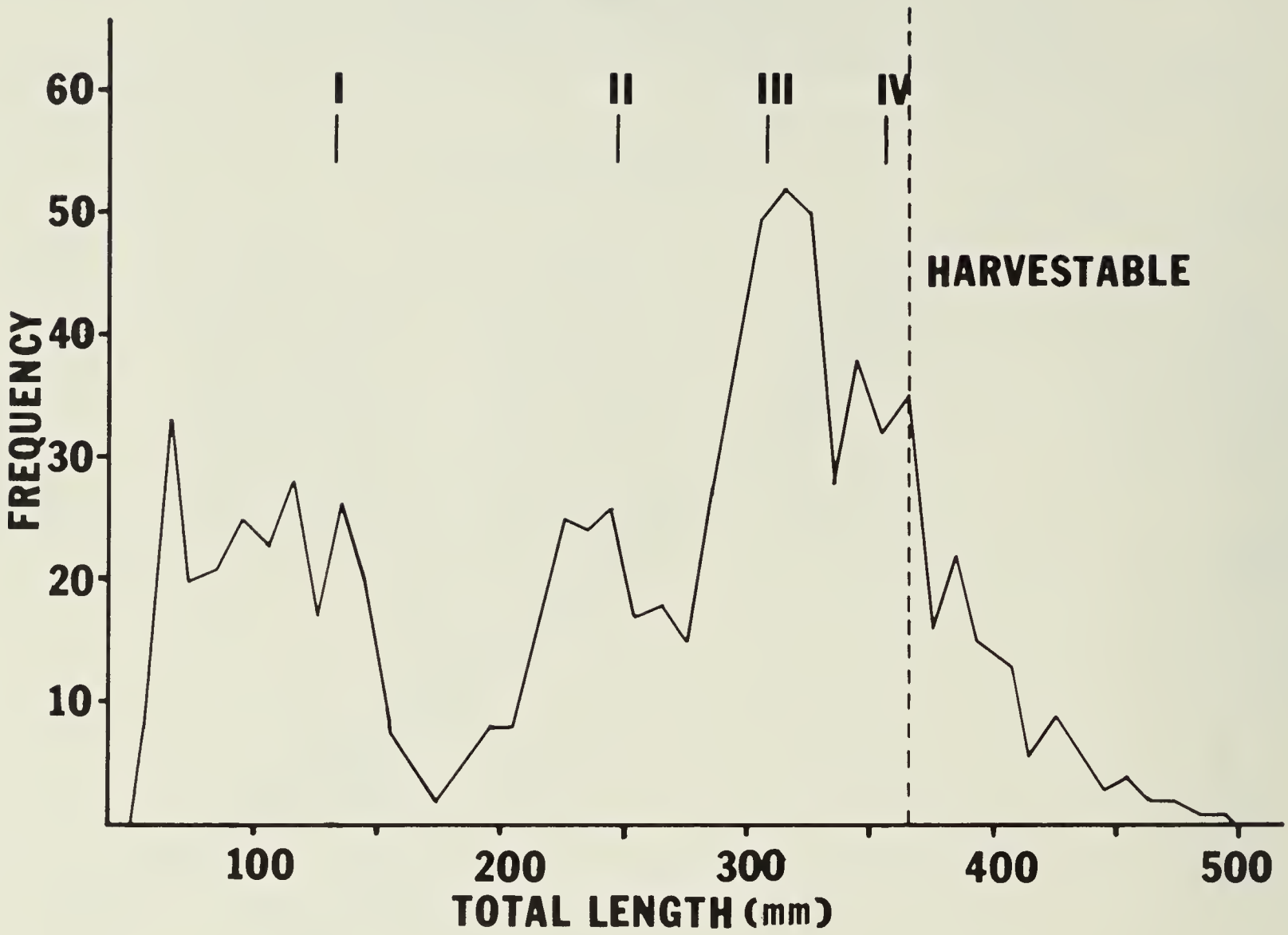

Figure 4. Length frequency distributions of largemouth bass collected from Lake Shelbyville, September 1979-1981, and mean lenghts at annulus formation based on back-calculation.

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ON THE DESIGN OF DIGITAL FILTERS WITH MONOTONIC TRANSITION REGIONS USING "DON'T CARE" BANDS.

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ABSTRACT

This paper is concerned with the problem of imposing monotonicity over the transition regions of the transfer functions of digital filters via conditions both mathematically sufficient and computationally convenient.

Ignoring the transition regions in the design formulation, i.e. treating them as "don't care" bands is, in some cases, sufficient for obtaining monotonic behavior over these regions. In this paper we give the conditions under which the use of a single "don't care" band is sufficient for imposing monotonicity over the transition region. The L_2 and L_∞ design formulations satisfy these conditions. This non obvious fact is well-known to filter designers, but its mathematical proof, to the authors' knowledge, has not yet appeared. The proof is valid for both Finite Impulse Response (FIR) filters and Infinite Impulse Response (IIR) filters.

However, when there are two or more transition regions, as in the case of multiband filters, ignoring the transition regions will, in general, not lead to the desired monotonic behavior. Therefore the design of multiband filters requires either the use of algorithms for unconstrained approximation with additional special techniques (e.g., [1,2]) or the use of algorithms for constrained approximation (e.g., [3-5]).

This paper presents the difficulties encountered in the multiband case when attempting to obtain monotonic transition regions by using alternate constraint sets based upon the use of "don't care" bands plus boundary conditions.

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I. INTRODUCTION

The traditional design requirements in the frequency domain for a filter are given in terms of desired performance over the pass and stop bands. In addition, there is an implicit requirement for monotonic behavior over those bands separating the pass and stop bands, i.e. the transition bands. In formulating the filter design problem as an approximation problem the typical approach is to approximate only over the pass and stop bands. This paper considers methods for imposing monotonicity over the transition bands which do not interfere with the approximation over the pass and stop bands [8].

One obvious approach for obtaining monotonicity over the transition bands is to formulate objective or desired functions over these bands and include these extra functions in any approximation or optimization. However, formulating this monotonicity objective is not a natual task for the filter designer. Furthermore, almost any monotonicity objective will interfere with the approximation over the pass and stop bands.

A second obvious approach is to either put upper bounds on the approximant or to constrain the sign of the derivative of the approximant over the transition bands. The computational efficiency of these "brute force" techniques is related to the filter order and to the size of the transition regions. Furthermore, they cannot be proven to be mathematically sufficient. Nevertheless they have been used in practice both because they can be effective and for the lack of better alternatives.

A third method that has been extensively used in the literature is to completely ignore the transition bands in the formulation of the approximation problem. That is, the transition bands are treated as "don't care" bands. There are cases where this approach does not work ([1,6]) and cases where this approach works, i.e. produces filters with monotonic transition bands. We will show that the success of this approach can only be guaranteed for filters with a single transition band. This technique, when it works, is the computationally simplest way to achieve a monotonic transition region.

Section II thoroughly examines the case of the single "don't care" band and presents a complete monotonicity theory. The analysis is accomplished by first stating general monotonicity conditions and then by showing that these are automatically met in certain design formulations with one "don't care" band, namely the L_∞ and L_2 formulations.

A consequence of this theory is that unconstrained minimax optimizaton algorithms are sufficient for the design of low and high pass filters formulated with one "don't care" band both for FIR and IIR filters.

Section III considers the case of multiple "don't care" bands. The sufficient conditions for monotonicity for two "don't care" bands require certain boundary conditions. These boundary conditions are shown to be too complicated to be automatically met by L_∞ or L_2 approximants. As a consequence the design of filters with two or more "don't care" bands requires algorithms for constrained approximation (unless the designer wants to try techniques based on empirical trial and error procedures [1,2]).

Unfortunately, a useful generalization of the "don't care" band approach, i.e. the determination of the boundary constraints on the derivatives that are necessary and sufficient to impose monotonicity over two to more "don't care" bands is a very difficult task. The specific difficulty is finding the most general

such constraints that are still practically interesting in an approximation setting. A way to pursue such a generalization together with the associated difficulties is discussed in Section III. As an examples, sufficient conditions for the "don't care" bands, are presented.

Section IV presents conclusions and indicates directions for future research.

II. ONE TRANSITION BAND

We will consider filters whose transfer functions are members of the class:

$$S[0,1]=\left\{R_{l,m}=\frac{\sum_{i=0}^{l}a_i x^i}{\sum_{i=0}^{m}b_i x^i} \;\middle|\; b_0=1;\quad x\in[0,1];\sum_{i=0}^{m}b_i x^i\neq 0 \quad x\in[0,1]\right\} \tag{1}$$

Each $R_{l,m}(x)$ is assumed to have no pole-zero cancellations. Furthermore, notice that the derivative with respect to x of any $R_{l,m}(x)$, which will be denoted as $R'_{l,m}(x)$ has no poles on $[0,1]$. Let $M=m+l$. The numerator of $R'_{l,m}(x)$ is a polynomial with degree at most $M-1$, therefore $R'_{l,m}(x)$ can have at most $M-1$ zeros on $[0,1]$.

Let $K=[0,b]\cup[c,1]$ with $0<b<c<1$, and $\mathring{K}=(0,b)\cup(c,1)$.

Finally define

$$d(x)=\begin{cases}1 & x\in[0,b]\\ 0 & x\in[c,1]\end{cases} \tag{2}$$

$$e(x)=R_{l,m}(x)-d(x) \tag{3}$$

$e'(x)$ denotes the derivative of $e(x)$ with respect to x, using appropriate right and left hand derivatives at the boundary points.

The first proposition we introduce states conditions over $[0,b]\cup[c,1]$ and at the boundary points {b,c} which are sufficient to guarantee that $R_{l,m}(x)$ is strictly monotonic in (b,c). This corresponds to the idea of characterizing certain sufficient conditions for monotonicity over the transition regions.

Proposition 1: If $R_{l,m}(x)\in S[0,1]$ approximates $d(x)$ and satisfies:

(i) $R_{l,m}(x)$ interpolates $d(x)$ at, at least M points in $\mathring{K}$

(ii) $e'(b)<0$, $e'(c)<0$

then $R_{l,m}(x)$ is strictly monotonic on (b,c), i.e.:

$$R'_{l,m}(x)\neq 0 \quad x\in(b,c) \tag{4}$$

Proof: Assume that $R_{l,m}(x)$ interpolates $d(x)$ at M_1 points in $(0,b)$ and at M_2 points in $(c,1)$, where $M=M_1+M_2$. By the mean value theorem, $R'_{l,m}(x)$ has M_1-1 zeroes on $(0,b)$ and M_2-1 zeros on (c,1), i.e. $R'_{l,m}(x)$ has a total of $M-2$ on $\mathring{K}$. Since $R'_{l,m}(x)$ has a numerator polynomial of degree $M-1$ and a denominator polynomial of degree 2m, these observations allow $R'_{l,m}(x)$ to be written as

$$R'_{l,m}(x)=(x-\alpha)Q(x) \qquad Q(x)\neq 0 \quad x\in[b,c]. \tag{5}$$

$Q(x)$ represents the rational function having as numerator the $M-2$ zeros of $R'(x)$ laying in $\mathring{K}$ and denominator equal of that of $R'_{l,m}(x)$.

Assumption (i) and decomposition (5) emphasize that $R'_{l,m}(x)$ has only one zero free to occur on (b,c).

Assumption (ii) is equivalent to

$$R'_{l,m}(b) < 0 \quad R'_{l,m}(c) < 0 \tag{6}$$

If $\alpha \in (b,c)$ then $b - \alpha < 0$ and $c - \alpha > 0$, therefore (6) implies $Q(b) > 0$ and $Q(c) < 0$. This is a contradiction since it implies $Q(x) = 0, x \in (b,c)$, contrary to the assumption (i) which is embodied in (5). Thus the (4) must hold.

It should be clear from the structure of $R'_{l,m}(x)$ in (5) that $R'_{l,m}(b)$ and $R'_{l,m}(c)$ cannot be simultaneously zero. $R'_{l,m}(b) = 0$ (and hence $R'_{l,m}(c) < 0$) implies $\alpha = b$, which still satisfies (4).

Similarly for $R'_{l,m}(c) = 0$.

□

Remark: The proof has been given for $R_{l,m}(x)$ interpolating $d(x)$ at M points only. The case of M + 1 interpolating points is trivially proven (assumption (i) being sufficient to prove (4), since $R'_{l,m}(x)$ has all its $M - 1$ zeros on $\mathring{K}$).

Given a sequence of points $x_1, x_2, \ldots$ in $[0,1]$ if

$$|e(x_i)| = \max_{x \in [0,1]} |e(x)| \tag{7}$$

and

$$e(x_i) = -e(x_{i+1}) \quad i = 1,2,\ldots.$$

$e(x)$ is said to alternate on the x_i's.

Proposition 2 strongly characterizes the behavior on $[0,b] \cup [c,1]$ of the rational approximants to $d(x)$ exhibiting the alternating property (7). Figure 1 illustrates the behavior by Proposition 2.

Proposition 2: A rational function $R_{l,m}(x) \in S[0,1]$ approximating $d(x)$ in such a way that $e(x)$ has, at least, $M + 2$ alternations on K has the following properties:

(a) b and c are extremal points of $e(x)$ on K

(b) $e(b) < 0 \quad e'(b) < 0 \quad e(c) > 0 \quad e'(c) < 0$

Proof: Since all the alternations of $e(x)$ correspond to local extrema of $R_{l,m}(x)$ (i.e. to zeros of $R'_{l,m}$) unless they occur at the boundary points {0,b,c,1} and since $R'_{l,m}(x)$ cannot have more than $M - 1$ zeros on $[0,1]$, the assumption of, at least, $M + 2$ alternations for $e(x)$ implies one of the following cases, namely $e(x)$ with:

(i) M − 1 extrema in $\mathring{K}$ and 4 extrema at {0,b,c,1}

(ii) M − 1 extrema in $\mathring{K}$ and 3 extrema at {0,b,1}

(iii) M − 1 extrema in $\mathring{K}$ and 3 extrema at {0,c,1}

(iv) M − 1 extrema in $\mathring{K}$ and 3 extrema at {0,b,c}

(v) M − 1 extrema in $\mathring{K}$ and 3 extrema at {b,c,1}

(vi) M − 2 extrema in $\mathring{K}$ and 4 extrema at {0,b,c,1}

Notice first that case (ii) or (iii) are contradictory, therefore they cannot occur. Case (ii), in fact can occur only by contradicting alternation as shown in Figure 2, or by calling for $R'_{l,m}(b) = 0$ as in Figure 3 which implies $R'_{l,m}(x)$ with one zero more that it can have. Similar argument proves the contradictory nature of case (iii).

Property a is satisfied in all the cases that can occur.

Property b is easily seen to be satisfied in all cases except (vi). If not, a further extremum of $R_{l,m}(\kappa)$ would exist in $[b,c]$, but $R_{l,m}(\kappa)$ is already assumed to have M − 1 extrema in K, and therefore cannot have another one.

One way to prove property b for case (vi) is exhaust all the possible situations for $e'(b)$ and $e'(c)$ to see that only those corresponding to property b are immune from contradiction. Let us distinguish the following 4 subcases:

Subcase I: $e'(b) = 0$, e'(c) = 0. Not admissible since it implies that $R'_{l,m}(\kappa)$ has M zeros.

Subcase II: $e'(b) = 0$, $e'(c) \neq 0$. Not admissible since if $e'(c) < 0$ then alternation is violated (see Fig. 4) and if $e'(c) > 0$ a further extremum exists in (b,c) (see Fig. 5). Therefore $R_{l,m}(\kappa)$ ends up with M extrema in [0,1] (namely M − 1 in K, one at b and one in (b,c)).

Subcase III: $e'(b) \neq 0$, $e'(c) = 0$. Not admissible by the same argument used in Subcase II.

Subcase IV: $e'(b) \neq 0$, $e'(c) \neq 0$.

This subcase specializes into 16 situations according to the specific signs of $e'(b)$, $e'(c)$ and $e(b)$, $e(c)$. Each one of these situations except the one $e(b) > 0$, $e(c) < 0$, $e'(b) < 0$, $e'(b) > 0$ (i.e. that satisfies property b) is contradictory since it violates at least one of the following points:

(A) $e(b)$ and $e(c)$ don't alternate

(B) the situation implies the existence of two further zeros of $R'_{l,m}(\kappa)$ in $[b,c]$ (this happens in the four subcases corresponding to $e'(b) > 0$ and $e'(c) > 0$).

(C) the sign of the derivative $R'_{l,m}(\kappa)$ at b or c contradicts the assumption that b or c is an extremal point. (An example of violation of point C is the situation $e(b) < 0$, $e(c) < 0$, $e'(b) < 0$, $e'(c) < 0$ shown in Fig. 6. Clearly b cannot be an extremal point.) Thus both (a) and (b) are satisfied.

□

A result embedded in Proposition 2 is that the rational approximants to d(x) exhibiting the alternating property "naturally" satisfy the assumptions of Proposition 1. The following Corollary makes this observation explicit.

Corollary: A rational function $R_{l,m}(\kappa) \in S[0,1]$ approximating $d(\kappa)$ in such a way that $e(\kappa)$ has at least $M + 2$ alternations on K is strictly monotonic in (b,c).

Proof: The occurrence of at least $M + 2$ alternations of $e(\kappa)$ in K implies that $R_{l,m}(\kappa)$ interpolates $d(\kappa)$ has at least M points in K. Therefore assumption i) of Proposition 1 is satisfied. Remember that by Proposition 2, property b $e'(b) < 0$ and $e'(c) < 0$. Therefore assumption ii) of Proposition 1 is also satisfied. Proposition 1 then guarantees that $R_{l,m}(\kappa)$ is strictly monotonic on $[b,c]$.

□

Thus the behavior of a rational approximant to $d(\kappa)$ over the whole [0,1] is strongly characterized by Proposition 2 and the Corollary. Fig. 7 illustrates this behavior, the key point being the values of $e(b)$, $e(c)$ and monotonicity over the transition region (b,c).

GENERALIZATIONS

1. In the above Propositions and Corollary, with obvious modifications, d(x) can be replaced by any f(x) corresponding to an e(x) = f(x) – R(x), with

$$e'(\kappa) = 0 \ \kappa \in K \Rightarrow R_{l,m}(\kappa) = 0 \ \kappa \in K \tag{13}$$

   For example high-pass filters satisfy (13). In general, all practical spectrum-shaping filters satisfy (13).
2. In the above Propositions and Corollary the error $e(\kappa)$ can be defined as

$$e(\kappa) = W(\kappa)(d(\kappa) - R_{l,m}(\kappa))$$

   with $W(\kappa) > 0$ and such that (13) is still fulfilled.

APPLICATIONS

The main advantage of Proposition 1 is that the sufficient conditions for monotonicity are in harmony with good approximating properties. As a confirmation that the monotonicity constraints over the transition band don't spoil the approximation over the pass and stop bands we note that the required conditions are spontaneously exhibited in several classes of approximants. For example, L_2 – optimal approximants satisfy the hypotheses of Proposition 1 [7,pp.111] as well as the L_∞ – optimal approximants, both polynomial and rational, as pointed out in the Corollary. Proposition 1 may also be useful in the construction of new filter design algorithms.

Proposition 2 represents a strong characterization over the pass and stop bands of the approximants with the alternation property (7). The main application of Proposition 2 is in connection with the Corollary. Together they guarantee that the L_∞ filter formulation with one don't care band is appropriate when monotonic behavior is desired over the transition band. Therefore any algorithm for unconstrained L_∞ approximation, e.g. the Remez algorithms for polynomials and for rational functions, and the Maehly algorithm, and the differential-corrector algorithm, deliver approximants with monotonic behavior over the "don't care" band. The Corollary of Proposition 2 is a generalization of a theorem given in [8] for the polynomial case only.

Comment

One can find many other types of pass-stop band and boundary conditions sufficient for strict monotonicity over one "don't care" band. For instance conditions involving less interpolating points and, of course, different boundary derivative requirements. These conditions have not been investigated because they do not correspond to interesting approximating properties.

III. SOME CONSIDERATIONS FOR THE CASE OF TWO OR MORE "DON'T CARE" BANDS

The practical utility of the propositions in the previous section is that they fully justify the use of unconstrained minimax approximation algorithms in pro-

blems with a "don't care" band over which a monotonic approximant is desired. Proposition 1 captures conditions sufficient for monotonicity over the transition region that are spontaneously satified by the best L_∞ approximant, both rational and polynominal. This fact is made explicit by Proposition 2 and the Corollary.

For approximation problems (minimax or other) with several transition regions the use of "don't care" bands alone is no longer sufficient to guarantee monotonic approximants over the transition regions. An efficient family of constraints, sufficient to guarantee monotonicity of the approximants on the transition regions, is based on the use of "don't care" bands together with constraints on the sign of the derivative of the approximant on the boundary of the transition regions. Clearly these constraints can only be exploited with constrained (minimax or other) approximation algorithms [4,5].

It is worthwhile devoting special attention to minimax approximation because it is particulary suitable to filter design formulations and it can be very computationally efficient.

Since monotonicity conditions for multiple "don't care" bands necessarily involve derivatives of more than first order. It is useful to distinguish between polynomial and rational functions. The latter turn out to be much harder to characterize.

For the special case of the two "don't care" bands and polynomial approximants (FIR filters) the following proposition gives an example of sufficient monotonicity conditions.

Proposition 3:

Notation:

Let $0 < b_1 < c_1 < b_2 < c_2 < 1$.

and

$K = [0,b_1] \cup [c_1, b_2] \cup [c_2, 1]$

$K = (0,b_1) \cup (c_1 b_2) \cup (c_2, 1)$

with

$$d_2(x) = \begin{cases} 1 & x \in [0,b_1] \\ 0 & x \in [c_1,b_2] \\ 1 & x \in [c_2,1] \end{cases}$$

$P(x)$ denotes a M-order polynominal with real coefficients

$P_m^{(i)}$ denotes the i-th derivative of $P_m(x)$ with respect to x.

Statement: If $P_m(x)$ approximates $d(x)$ satisfying the following conditions:

(i) $P_m(x)$ interpolates $d(x)$ at, at least, $M-1$ points in $\overset{\circ}{K}_2$

(ii) $P_m^{(1)}(b_1) < 0 \quad P_m^{(1)}(b_2) > 0$

$P_m^{(1)}(c_1) < 0 \quad P_m^{(1)}(c_2) > 0$

(iii) $P_m^{(2)}(b_1) < 0 \quad P_m^{(2)}(b_2) > 0$

$P_m^{(2)}(c_1) > 0 \quad P_m^{(2)}(c_2) < 0$

(iv) $P_m^{(4)}(b_1) > 0 \quad P_m^{(4)}(b_2) < 0$

$P_m^{(4)}(c_1) < 0 \quad P_m^{(4)}(c_2) > 0$

then $P_m(x)$ is strictly montonic on $\bigcup_{i=1}^{2} (b_i, c_i)$, i.e., $P_m(x) \neq 0 \quad x \in \bigcup_{i=1}^{2} (b_i, c_i)$.

Proposition 3 is presented here without proof since it is primarily meant to be an illustration of the type of monotonicity constraints that could be used for polynomial approximants. It is worth noting that the constraints of Proposition 3 are linear in the derivatives. The number of the constraints is independent of the size of the transition bands and they result in approximants strictly monotonic on the transition regions. Unfortunately the number of constraints grows with the number of "don't care" bands, and even the case of three "don't care" bands turns out to be rather cumbersome.

If it is desired that the monotonicity conditions be oriented toward minimax approximation then it is reasonable to tailor them to describe the largest class of L_∞ approximants monotonic over the "don't care" bands. This is equivalent to requiring that the monotonic approximants interpolate the target function at least $M + 2 - (B \times 2 + 2) + B + 1 = M - B + 1$ points, where B represents the number of "don't care" bands. (This is the reason for the assumption (i) in Proposition 3.) Imposing a number of interpolating points greater than this can greatly simplify the boundary conditions on the derivatives. But this amounts to considering only a subclass of all the possible monotonic approximants. Similarly, it is restrictive to search among the class of monotonic approximants with zero derivatives of fixed order at the boundary points.

Conditions (ii)-(iv) of Proposition 3 are certainly sufficient to characterize monotonic behavior over the "don't care" bands among the class of polynomials satisfying condition (i) of Proposition 3. However they don't describe the entire class of polynomials having monotonic behavior over two "don't care" bands. The conditions describing this class are not yet clear. Thus we view Proposition 3 as an example of the possible conditions but do not suggest that it presents the best, or even the most practical, way of achieving monotonicity over two transition regions.

We note that there could exist nonlinear conditions on the derivatives of the approximant at the boundary point or at other specified points, capable of guaranteeing monotonicity in a more synthetic manner than conditions of the type used in Proposition 3. The search for the most synthetic or convenient way to impose monotonicity over the "don't care" bands for classes of approximants interpolating the objective functions at, at least, M-B + 1 points is an open and relatively unexplored research question.

The considerations in this section are meant to indicate what kind of results are presently missing in order to use multiple "don't care" bands in filter design while keeping the same generality that Section 2 illustrates for filter design with a single "don't care" band.

IV. CONCLUSION

This paper has investigated the conditons under which a "don't care" band approach to transition regions leads to monotonic behavior over these regions. Such a technique is analyzed because it seems the computationally most convenient. Section II clearly shows the cases when the use of a single "don't care" band is sufficient to impose monotonicity on the "don't care" band. L_∞ and L_2 filter design formulations belong to these cases. The results are valid both for FIR as well as IIR filters.

Section III shows why the simple "don't care" bands are not adequate to impose monotonicity if the number of transition regions is greater or equal to two. The next best approach seems to be the use of "don't care" bands together with derivative conditions at certain specified points. Secion III gives a set of sufficient conditions for the two transition region problem. However, a general approach and solution to the multiple transition region design problem remains an open research question.

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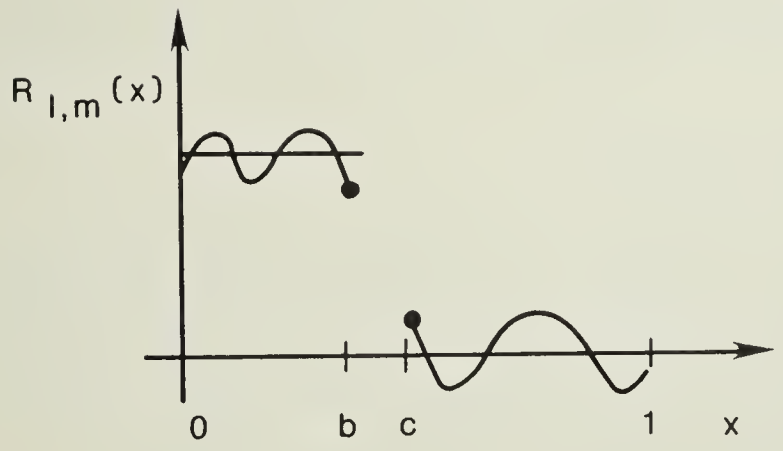

Figure 1. Filter behavior imposed by Proposition 2.

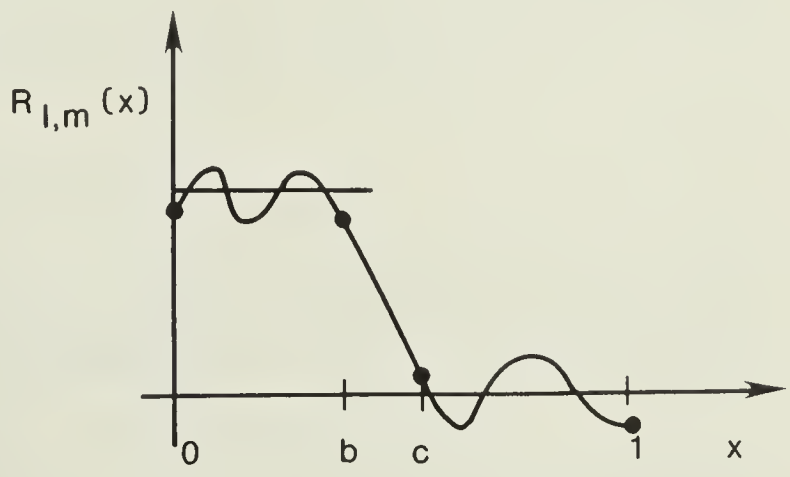

Figure 2. Illustration of contradicting alternation in Proposition 2.

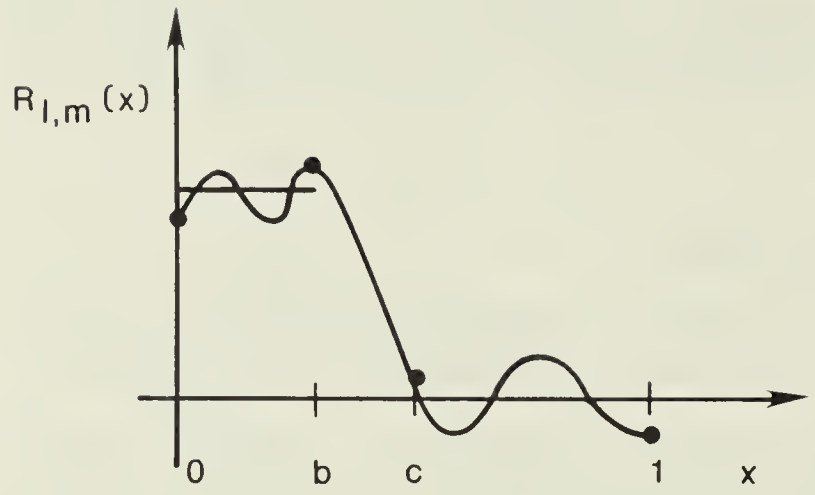

Figure 3. Illustration requiring too many zero's in Proposition 2.

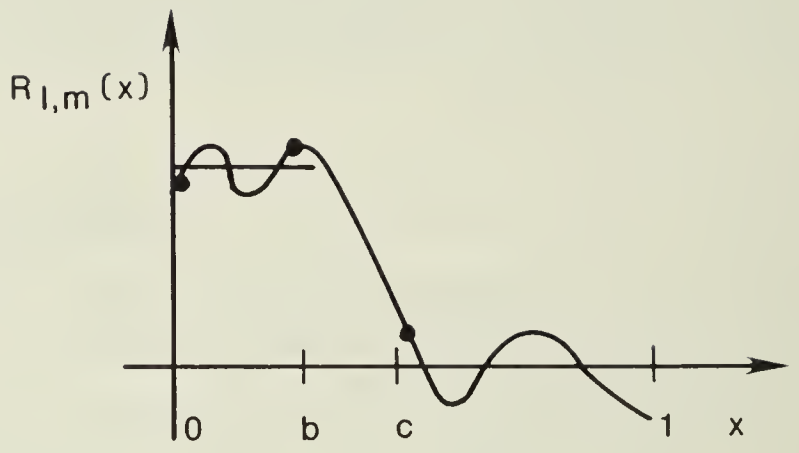

Figure 4. Illustration of Subcase II, Proposition 2.

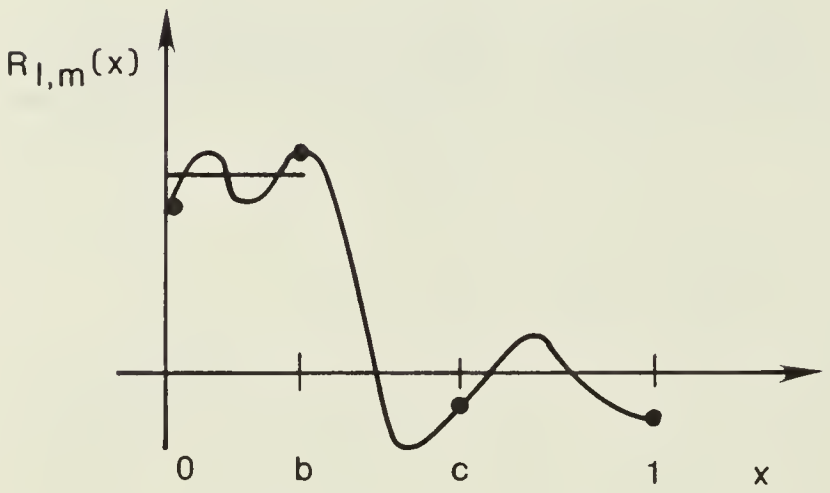

Figure 5. Illustration of Subcase II, Proposition 2.

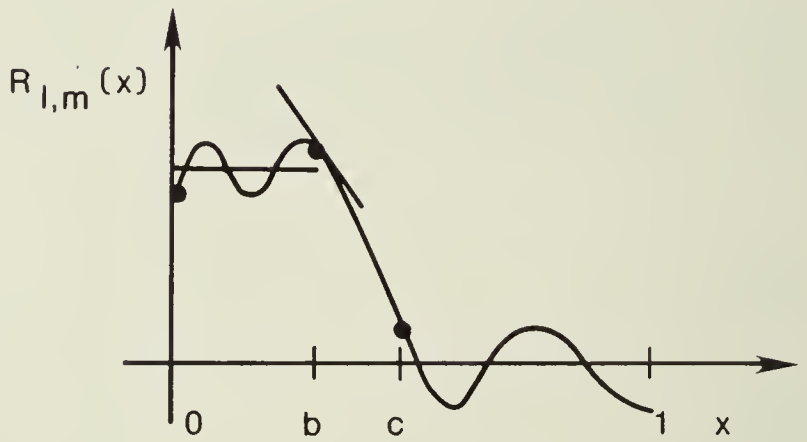

Figure 6. Illustration of Subcase IV, Proposition 2.

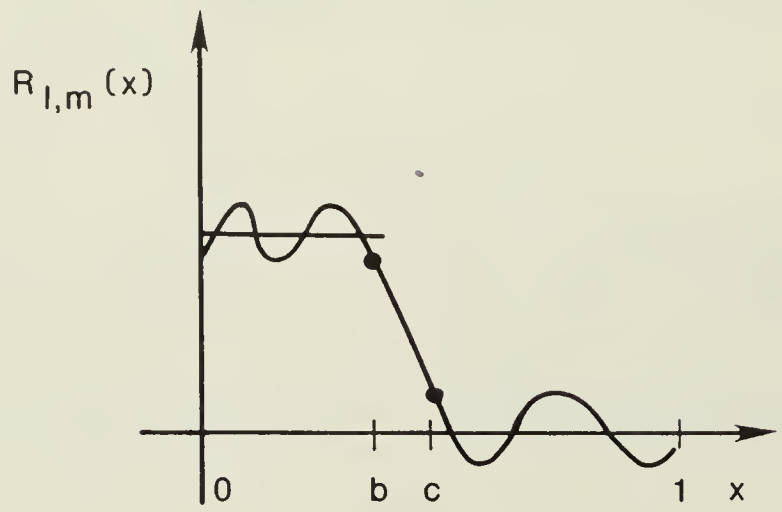

Figure 7. Behavior of rational approximant as characterized by Proposition 2 and the Corollary.

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BAILEY LIMESTONE (LOWER DEVONIAN) OF SOUTHWESTERN ILLINOIS: A CARBONATE TURBIDITE

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ABSTRACT

The Bailey Limestone (Lower Devonian) of southwestern Illinois consists of approximately one hundred complete and incomplete superpositions, decimetric in thickness, of the following five microfacies: Ml: graded bedded to massive coarse-grained crinoidal calcarenite, M2: incipiently graded to parallel laminated fine-grained crinoidal calcarenite, M3: parallel laminated crinoidal and pelletoidal biocalcisiltite, M4: massive to laminated spiculitic and pelletoidal biocalcisiltite, M5: massive pelletoidal bioclastic micrite. The sedimentary structures and textures of the microfacies are those of the A-B-C-D Bouma sequence in which units A through D are interpreted as turbidity current deposits, and unit E as interturbidite sediment. Application of Walker's index of proximality P permits reconstruction of the vertical evolution of the sequence as representing a submarine fan system which displays oscillations from inner fan through mid- and outer-fan into basin plain subenvironments. The Bailey Limestone is the first carbonate turbidite reported in the Paleozoic depositional history of the Illinois Basin.

INTRODUCTION

The Bailey Limestone is the basal unit of the Lower Devonian Series in the Illinois Basin (Willman *et al.*, 1975). It underlies a large portion of the deepest part of the basin, reaches a maximum thickness of 120 meters, and is partially exposed in high cliffs of the Mississippi River bluffs in southwestern Illinois.

The Bailey Limestone consists of approximately one hundred thin to medium-bedded couplets (10-15 cm thick) of limestones and cherty limestones or cherts displaying the characteristic sedimentary structures of turbidites (Bouma sequence), among which sole markings and graded bedding are prominent.

Carbonate turbidites are relatively rare in cratonic basins where they occur

during the initial phases of filling. The Bailey Limestone is the first case of this type of carbonate deposition reported in the Illinois Basin.

TECTONIC FRAMEWORK

During Silurian to Early Devonian times a structural depression, called the Metropolis Depression (Rogers, 1970), occupied the southern portion of the Illinois Basin, and extended southwestward beyond the pre-Cretaceous truncation into the Mississippi Embayment (Fig. 1). During Early to Middle Silurian times, the depression was maintained because of the inability of carbonate sedimentation to fill more than the marginal areas of the subsiding Illinois Basin. During Late Silurian times, carbonate shelves related to reef development prograded from east and west and coalesced forming a platform which bordered the Metropolis Depression. Following a lowering of sea level at the end of Silurian times, the platform was subaerially exposed as a low lying landmass and the shoreline located high on its seaward slope. The platform was the source of substantial sediments transported into the depression. Fine-grained detrital quartz, silica, and argillaceous materials were eroded from older sediments exposed on the shelves whereas the relatively coarse-grained, shallow water components (crinoids, sponge spicules and glauconite) were of primary derivation from the shelf foreslope environments.

Deposition of sediments in the depression began in latest Silurian to Early Devonian times (Collinson, 1967; Rogers, 1970) and the resulting sequence is represented by Randol Shale, Bailey Limestone, Grassy Knob Chert, Backbone Limestone, and Clear Creek Chert. These units attain a maximum thickness of nearly 400 meters in the center of the Metropolis Depression (Rogers, 1970) and their geometry (Fig. 2) shows that they gradually filled the depression.

METHODS

The investigated section is a vertical cliff in a rugged wooded area called Pine Hills along the Mississippi River bluffs, located about eight kilometers southeast of Grand Tower, Union County (Wolf Lake Quadrangle, SE. 1/4, SW. 1/4, NE. 1/4, Sec. 16, T. 11 S., R. 3W).

The exposed column is 40 meters thick and was sampled at an average vertical interval of 10 centimeters in order to provide an adequate representation of the style of deposition of the turbidites. More than 400 thin sections oriented perpendicular to bedding were prepared and subjected to a detailed petrographic study following the statistical techniques used by Carozzi and coworkers for microfacies investigations (see for instance, Okhravi and Carozzi, 1983). This method calls for measuring indexes of clasticity and frequency of all detrital components, mineral or biogenic, and frequency of all in-place biogenic components over standard areas of the thin sections. These data are interpreted in terms of paleoenvironmental factors such as energy of transporting agents, and in terms of paleoecology of the various benthic and planktic biota. In this particular study (Banaee, 1981), clasticity indexes were determined for crinoid bioclasts, detrital quartz and glauconite grains. Frequency indexes were determined for bioclasts including crinoids, ostracods, brachiopods, sponge spicules, trilobites, radiolarians, and glauconite grains. The proportions of total bioclasts, matrix (bioclastic and/or lithic

pelletoidal), cement, and pyrite were established on the total surface area of a thin section in percentages (total bioclasts + matrix + cement + pyrite = 100%). The intensity of bioturbation was expressed in percentages as follows: 25% for low, 50% for medium, and 75% for high degree of bioturbation. Microscopic sedimentary structures such as massive or laminated structures or graded bedding were also recorded on standardized data sheets.

MICROFACIES

After detailed petrographic investigation, the thin sections were divided into five distinct microfacies on the basis of size, frequency and type of biogenic components, proportions of matrix (bioclastic and/or pelletoidal), total bioclasts and sedimentary structures. The validity of the five microfacies was verified by an INTERIM computer program (Demirmen, 1969), and the inter-relationships be tween microfacies were established by multivariate correlation of mean values of components against their respective microfacies using the SOUPAC correlation coefficient program (SOUPAC, 1976).

The microfacies are briefly described below in order of decreasing grain size, decreasing proportion of benthic bioclasts, increasing proportion of planktic bioclasts, and increasing amount of pelletoidal matrix (Fig. 3). These trends indicate a gradual decrease in the hydraulic energy of the transporting agent as expressed in turbidity current deposition.

Microfacies 1: coarse-grained crinoidal biocalcarenite with association of syntaxial rim cement and bioclastic matrix, texture graded bedded to massive, bioturbation low.

Microfacies 2: fine-grained crinoidal biocalcarenite with bioclastic to pelletoidal matris, texture incipiently graded bedded to parallel laminated, bioturbation medium.

Microfacies 3: crinoidal and pelletoidal biocalcisiltite with scattered sponge spcules and radiolarians, texture parallel laminated, bioturbation medium to high.

Microfacies 4: spiculitic, pelletoidal biocalcisiltite, texture massive or laminated, bioturbation high.

Microfacies 5: pelletoidal bioclastic micrite, texture massive, bioturbation medium.

IDEAL DEPOSITIONAL SEQUENCE

The average values of the measured petrographic paramenters allow to prepare a graphic representation of an ideal complete depositional sequence of the above-described five microfacies, interpreted by means of an energy level curve (Fig. 4). The behavior of the various parameters can be summarized as follows.

The curves representing the frequency and clasticity of crinoids, the frequency of ostracods, brachiopods, trilobites, total bioclasts, cement and the frequency and clasticity of glauconite grains display a decrease upward. The curves expressing the frequency of sponge spicules, the percentage of pelletoidal matrix, and the intensity of bioturbation (until microfacies 4) show an increase upward.

The curves showing clasticity of detrital quartz grains and frequency distribution of radiolarians show an increase and then a decrease upward. They both display a peak in microfacies 3, for quartz it is 0.10 mm. Because the average size of radiolarians is 0.18 mm, their frequency peak appears also size controlled. The

curves showing the behavior of bioclastic matrix and of pyrite are random. The energy level curve of the transporting agent decreases upward through the superposed microfacies.

In summary, the ideal depositional sequence (microfacies 1 through 5) shows that relatively coarse-grained detrital biogenic components (dominated by benthic fauna) are replaced gradually by smaller and lighter detrital (quartz) and biogenic components (planktic radiolarians, sponge spicules), and pelletoidal matrix. These variations are accompanied by sedimentary structures ranging from sole markings and erosional features at the base of beds through graded bedding to laminated and massive. The association of all these textural and compositional features indicates a mechanical redeposition of the entire sequence by waning hydraulic energy in a relatively deeper water environment.

The ideal sequence is similar to the fining upward sequence typical of deposition by turbidity currents in detrital siliciclastic sediments, and known as the Bouma sequence (Bouma, 1962). It consists of the turbidite units A, B, C, D, and the interturbidite unit E (Fig. 4). Complete Bouma sequences are relatively rare and incomplete sequences more commonly found (BCD, BC, CD, AD, etc.). This observation also applies to the carbonate turbidites of the Bailey Limestone (Fig. 5).

ORIGIN OF COMPONENTS

Bioclasts including crinoids, ostracods, brachiopods, trilobites, sponge spicules and detritial glauconite grains probably originated from the shelf foreslope or slope environments and are sub-contemporaneous with deposition. Radiolarians were contemporaneous planktic fauna. Detrital quartz grains occurring in limited size range, are probably recycled from Silurian or finely arenaceous earlier deposits. Silica (responsible for early chertification) and clay minerals were also derived from older Silurian sediments.

VERTICAL EVOLUTION OF INVESTIGATED SECTION

The typical succession of numerous carbonate turbidites which forms the Bailey Limestone is well expressed by the detailed graphic representation of the variations of the parameters and the energy curve interpretation (Banaee, 1981). A typical example of the 30 to 40 meters interval is sufficient (Fig. 6). However, since the present study dealt only with one vertical column it was not possible to establish by direct observation the evolution in time and space of the corresponding submarine fan. This situation of insufficient outcrops is not unusual also among siliciclastic turbidites in the flysch of mountain ranges. An elegant and successful technique for interpreting the evolution of the depositional environment of turbidites under such conditions has been proposed by Walker (1967). It uses the concept of proximality, that is the assumed distance along the basin slope from the point where deposition by turbidity currents begins. Walker divided turbidite sequences into groups based on changes in the thickness and/or frequency of occurrence of individual units of the Bouma sequence. He proposed a proximality index $P = A + 1/2\ B$, in which A and B are the percentage of beds in each group beginning respectively with unite A and B, hence P varies from very proximal (100%) to very distal (0%).

The Bailey Limestone sequence having been subdivided into individual units (microfacies 1 to 5, equal to A to E in the Bouma sequence) on the basis of

petrographic observations and not according to megascopic field observations, it was necessary to modify accordingly the techniques of obtaining Walker's P index. By means of appropriate subroutines of INTERIM computer program (Banaee, 1981), the frequency of occurrence of individual Bouma's divisions and their associations (corresponding to individual microfacies and their types of superpositions) were plotted at an arbitrarily selected constant interval of 1.5 meters (10 control points) of the stratigraphic section (Fig. 7). The values of P were calculated for the same interval. The numerical values of P vary for the entire section from proximal (60%) to very distal (0%). The value of P was equal to zero in two cases: where microfacies 1 (A) and 2 (B) were absent, and where there was only microfacies 5 (E).

The general trend of the stratigraphic variation of the P index (Fig. 7) displays three successive highs (at 5-7, 17, and 29-30 m.) separated by lows, followed by a final rise terminating at 40 m. A comparison with recognized depositional subdivisions of submarine fans (Mutti and Ricci-Lucchi, 1972; Mutti, 1974; Walker, 1969, 1978; Cook, Hine and Mullins, 1983) permits further interpretation of the variation in time of the P index in terms of inner, middle, and outer fan environments, as well as basinal plain environments (Fig. 7), that is in general terms of decreasing energy or increasing relative depth.

CONCLUSIONS

The Bailey Limestone (Lower Devonian) in southwestern Illinois consists of approximately one hundred complete and incomplete superpositions of five distinct carbonate microfacies which display the characteristics of the A-B-C-D-E Bouma sequence and are interpreted as carbonate turbidites. Application of Walker's index of proximality P permits reconstruction of the vertical evolution of the investigated sequence as representing a submarine fan system which displays oscillations from inner fan through mid and outer fan into basin plain subenvironments.

ACKNOWLEDGMENTS

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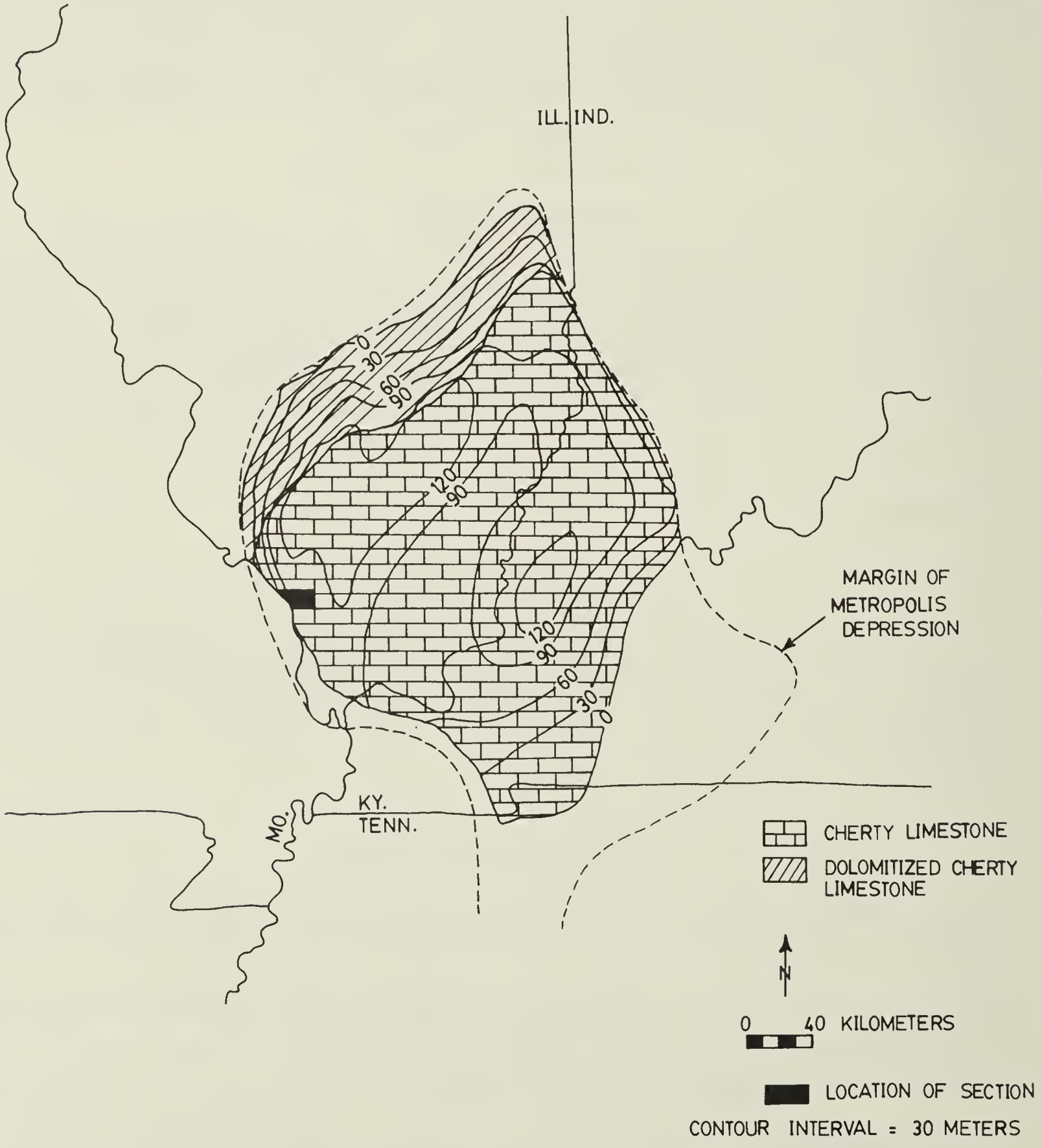

Fig. 1. Isopachs and lithofacies of Bailey Limestone (modified from Rogers, 1970).

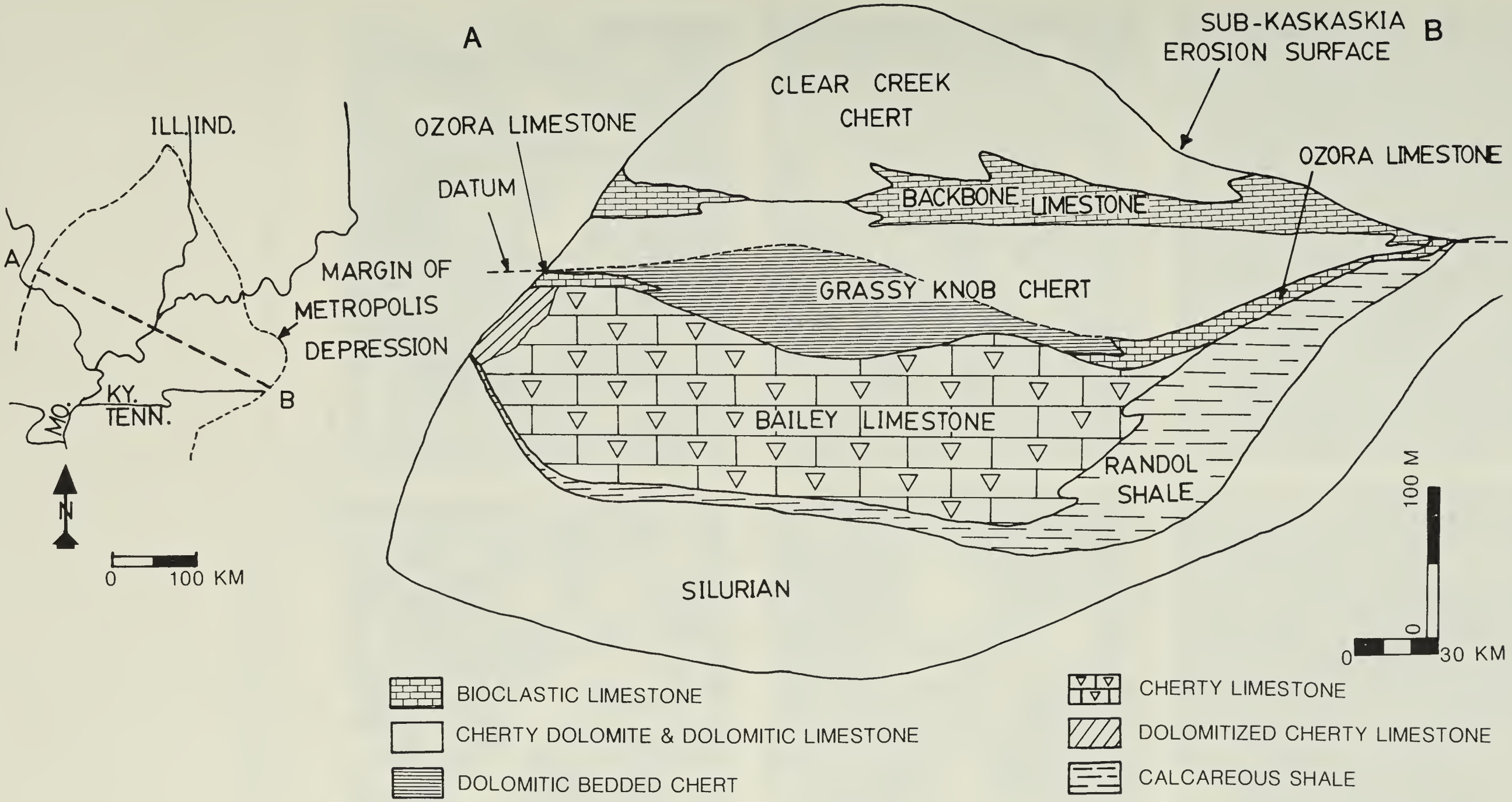

Fig. 2. Lithologic cross-section of the Uppermost Silurian and Lower Devonian rocks in Metropolis Depression (modified from Rogers, 1970).

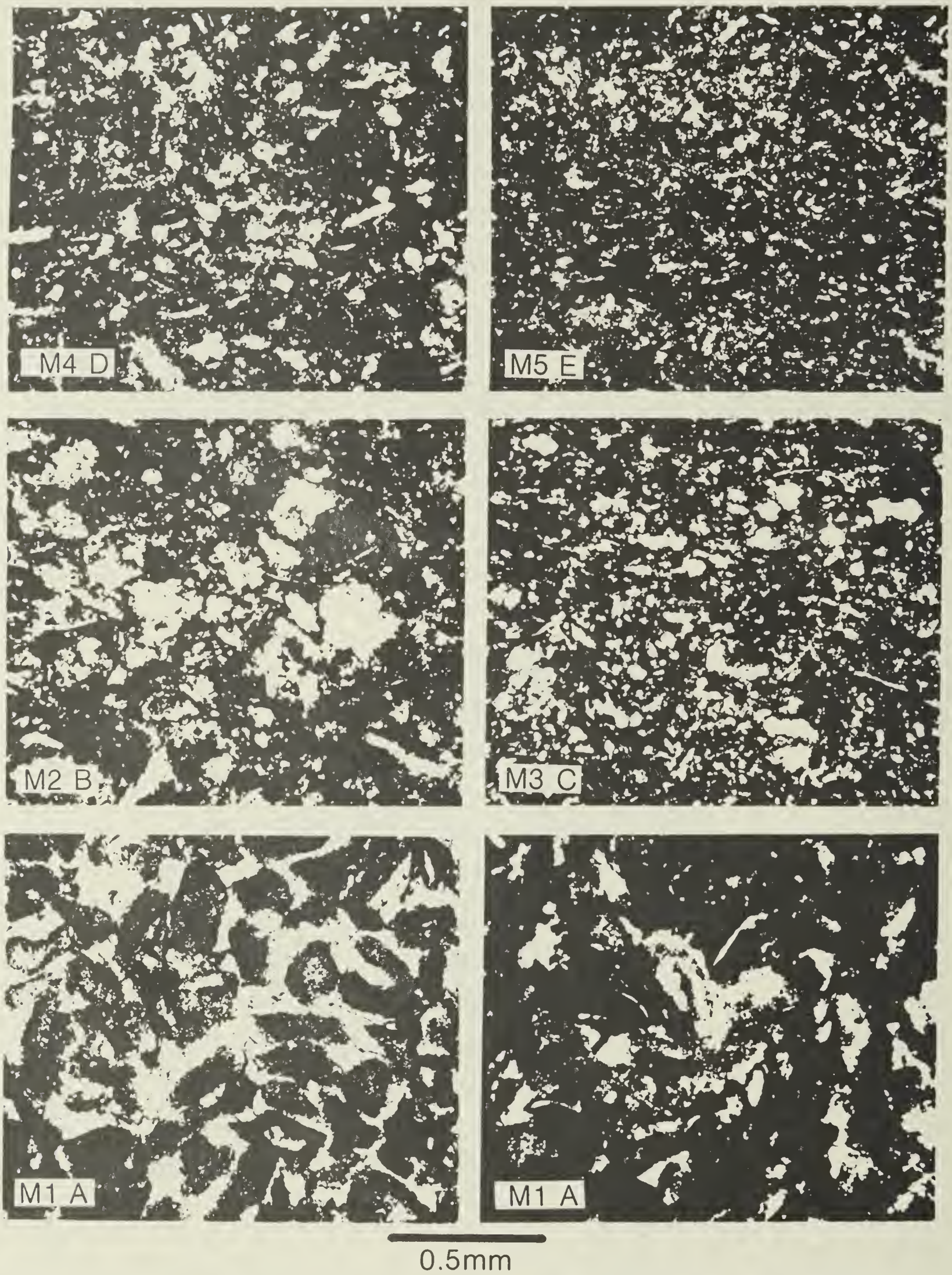

Fig. 3. Photomicrographs of microfacies M1 to M5 in order of superposition (A to E of Bouma sequence). Plane polarized light.

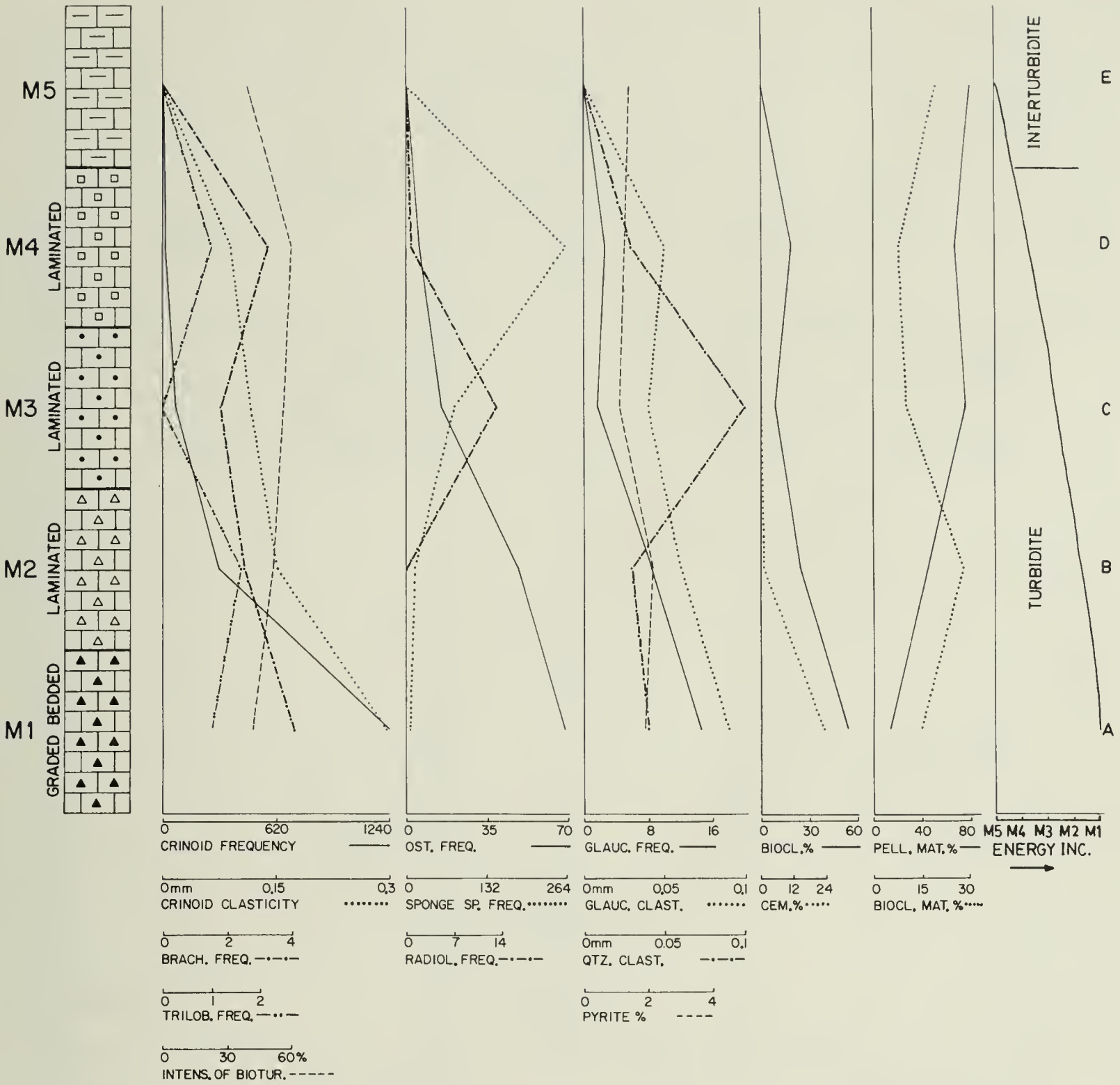

Fig. 4. Ideal depositional sequence (microfacies M1 to M5).

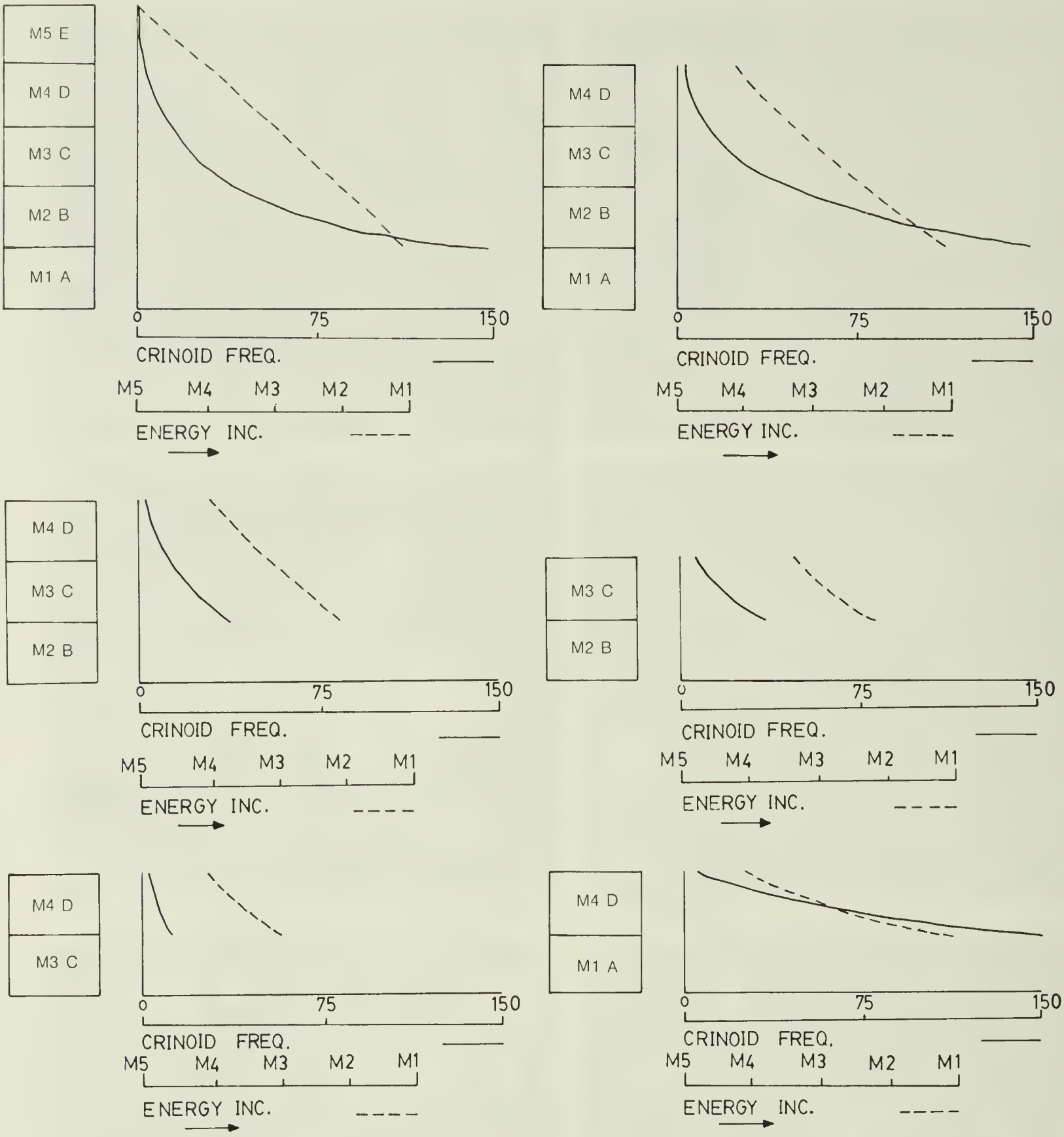

Fig. 5. Incomplete Bouma sequences.

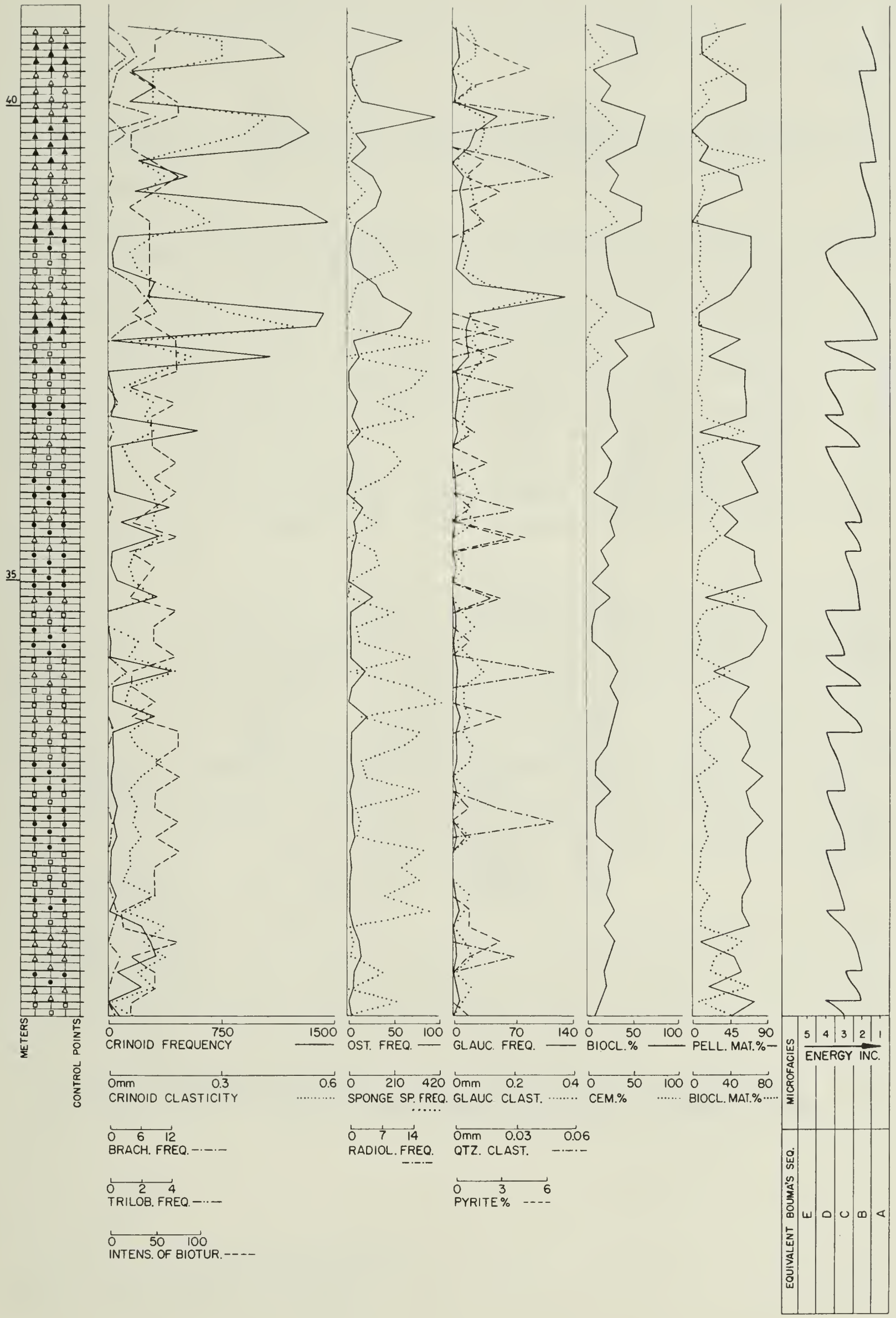

Fig. 6. Example of detailed graphic representation and interpretation of investigated section (30 to 40 m. interval).

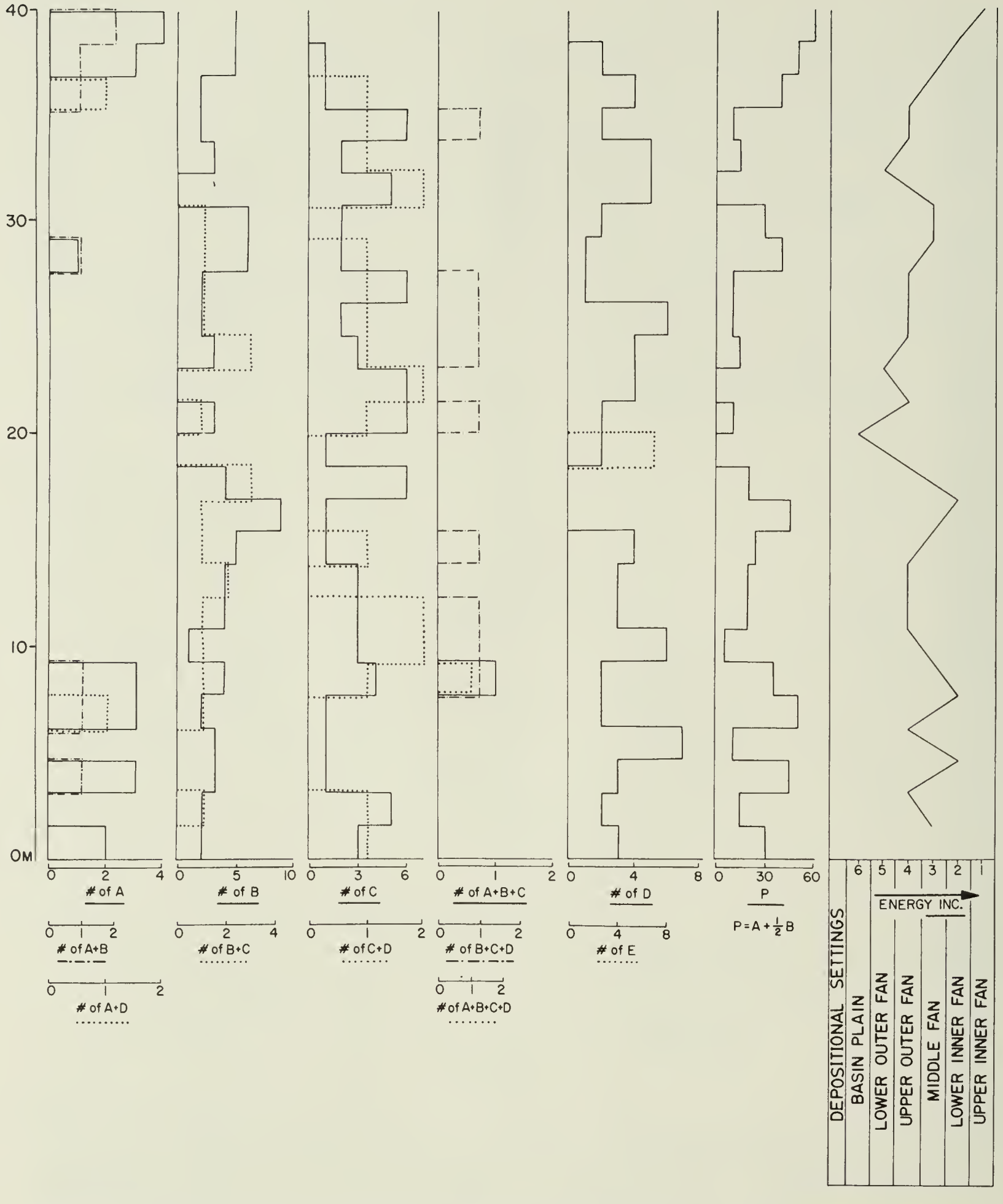

Fig. 7. Vertical variation of individual units of Bouma sequence, of complete and incomplete Bouma sequences, of P index, and environmental interpretation of investigated section.

LETTERS-TO-THE-EDITOR/NOTES

Dear Sir:

I read recently a review concerning toxicities of natural foods in TRANACTIONS (1983, 76, 181) in which a number of claims are made concerning Alliums and glucosinolates.

The author, Dr. Kaplan, states that onions contain "a toxic principle thought to be an alkaloid". In actual fact there is little evidence to support the occurence of alkaloids in onions. One isolated report claims an alkaloid ("identified" by chemical tests) from cows that had acute anaemia after eating onions (J.A.V.M.A., 129, 75, 1956) but the nature of the tests and subsequent information concerning the proposed alkaloid has not been published. It is more likely that the principle responsible for onion toxicity is n-propyl disulphide (the prefix denoting the linear shape of the molecule and not to be confused with an upper-case N which indicates the presence of nitrogen in the molecule). This compound is a non-nitrogenous, pungent, volatile oil which is derived enzymatically from a precursor, n-propyl-L-cysteinesulphoxide and is responsible for many of the flavour attributes of onion.

Dr. Kaplan also claims the presence of glucosinolates in plants of the genus *Allium*. This class of thioglycosides is exclusively limited to the *Capparales* and are particularly important in brassicaceous crops. They are completely absent from Alliums (as are their breakdown products). The effect of glucosinolates on thyroid metabolism is due to two separate breakdown products, and not the parent glucosinolates *per se*. From the glucosinolate progoitrin (2-hydroxybut-3-enyl glucosinolate), enzymic hydrolysis by a co-occurring thioglucosidase produces vinyloxazolidinethione (goitrin) which, as the trivial name suggests, is goitrogenic, The activity of the compound is not, however, due to competition with iodine and increasing iodine supplementation in the diet will not alleviate the problem (*CRC Crit. Rev. Fd Sci Nutr.*, 1983, 18, 123).

Certain other glucosinolates (notably, those derived biogenetically from tryptophan) give rise, upon enzymic hydrolyses, to unstable isothiocyanates which decompose spontaneously to give thiocyanate ion as a product. It is this latter compound which competes with iodine and thus causes giotrogenic activity. Heat serves to inactivate the endogenous thioglucosidase activity thereby preventing decomposition of the glucosinolates to the goitrogenic side products.

I hope this serves to clarify matters concerning glucosinolates, Alliums and Brassicas.

Yours sincerely,

A.B. Hanley
Chemistry & Biochemistry Division
AFRC Food Research Institute
Norwich NR4 7UA, Great Britain

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A NEW DISTRIBUTION SUGGESTED FOR THE RICE RAT *(Oryzomys palustris)* IN SOUTHERN ILLINOIS

John E. Casson[1]
Cooperative Wildlife Research Laboratory
Southern Illinois University
Carbondale, Illinois 62901

ABSTRACT

Predator food habit investigations occasionally reveal new distributions for small mammals. This is logical as predators are more adept at capturing their prey than are man's trapping techniques. Sealander (1943) reported an extension to the distribution of the snowshoe hare (*Lepus americanus*) in Michigan as a result of a food habit study on mink.

During a study of mink diet in southern Illinois (Casson and Klimstra 1983), a new distribution record for the rice rat was suggested. Previous reported distribution in Illinois was restricted to regions of Jackson and Williamson counties and southward (Klimstra and Roseberry 1969). Samples of mink stomachs yielded two rice rats; one intestinal tract was from Washington County, substantially north of the reported distribution of this uncommon rat. Because rice rats have been collected from the southern drainage areas of the Big Muddy River, it is possible that they also occur in more northern portions, parts of which are located in Washington County. Small mammal trapping in this watershed might result in confirmation of the new distribution.

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Casson, John E., and W.D. Klimstra. 1983. Winter foods of mink in southern Illinois. Trans. Illinois State Acad. Sci. 76:281-292.

Klimstra, W.D., and J.L. Roseberry. 1969. Additional observations on some southern Illinois mammals. Trans. Illinois State Acad. Sci. 62:413-417.

Sealander, J.A. 1943. Winter food habits of mink in southern Michigan. J. Wildl. Manage. 7:411-417.

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Correspondence to:
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Reply

Dear Sir:

The claims and counterclaims concerning the toxicity of many foods are legion. This statement is especially true for the responsible priciples. For this reason I have tried to avoid overly assertive statements and, if anything, I have understated the worldwide potential for food damage, much of which is unknown, uncertain or even concealed. A review of this area should include contentious statements from refereed sources and this view was taken in the paper.

No view on a dynamic subject has lasting value if it stirs up no interest or reaction. Dr. A.B. Hanley has submitted strong evidence that alkaloids are not the principles responsible for toxicity in onions nor glucosinolates the factors present in the genus *Allium*. These statements contribute meaningfully to the literature and I regret that Dr. Hanley's information was not available to me when my review was written. The fact remains that the toxicities do occur as I stated, although the obscurity lies for the most part in the identification of the chemicals responsible for the toxic effects in the plants in question.

Sincerely,

Harold M. Kaplan
Southern Illinois University
School of Medicine
Carbondale, Illinois 62901, USA

A Follow-up

Dear Sir:

One point which, it occures to me, I failed to mention in my original communication concerns the goitrogenicity of members of the genus *Allium*. As Dr. Kaplan correctly states, onions can be goitrogenic. This effect, however, is considered to be due mainly to the presence of n-propyl-disulphide although a number of other mono- and di-sulphides have similar effects (*Nature*, 211, 87, 1966; *Eur. J Pharmacol*, 16, 251, 1971). It was not my intention to deny the presence of goitrogens in onions, merely to emphasise the non-glucosinolate origins of the active compounds. I hope this resolves any ambiguity in my original letter.

Thank you for your interest.

Sincerely,

A.B. Hanley

Dear Sir:

Please accept and publish the following letter in the *Transactions of the Illinois State Academy of Science:*

FLORA OF THE UNION COUNTY CONSERVATION AREA, ILLINOIS

A floristic study of the Union County Refuge was completed in 1982 which included an annotated checklist of species and descriptions of six plant communities. Voucher specimens were deposited in the SIU-Carbondale Herbarium. My apologies for this long-overdue information.

Gail Westmoreland
Box 32
Garden City, IA 50102

Should you wish to submit a LETTER-TO-THE-EDITOR, please address it to:

Dr. Barry A. Fiedel
Editor, TRANSACTIONS
Department of Immunology
Rush Medical Center
1753 W. Congress Parkway
Chicago, Illinois 60612, USA

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